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Geotechnical Analysis Report for July 2000–June 2001

September 2002

Waste Isolation Pilot Plant

FOREWORD AND ACKNOWLEDGMENTS

This report contains an assessment of the geotechnical status of the Waste Isolation Pilot Plant (WIPP). During the excavation of the principal underground access and experimental areas, the status was reported quarterly. Since 1987, when the initial construction phase was completed, reports have been published annually. This report presents and analyzes data collected from July 1, 2000, to June 30, 2001.

This Geotechnical Analysis Report was written to meet the needs of several audiences. This report satisfies the requirements presented in the WIPP Hazardous Waste Permit[1] and the certification of compliance[2] with Title 40 *Code of Federal Regulations(CFR)* Parts 191 "Environmental Radiation Protection for Management and Disposal of Spent Fuel, High-Level and Transuranic Radioactive Wastes" and 194, "Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations". It focuses on the geotechnical performance of the various components of the underground facility, including the shafts, shaft stations, access drifts, and waste disposal areas. The results of investigations of excavation effects and other geologic studies are also included. The report compares the geotechnical performance of the repository to the design criteria. It describes the techniques that were used to acquire the data and the performance history of the instruments. The depth and breadth of the evaluation of the different components of the underground facility vary according to the types and quantities of data available and the complexity of the recorded geotechnical responses. Graphic documentation of data and tabular documentation of instrument history can be provided upon request.

This Geotechnical Analysis Report was prepared by Westinghouse TRU Solutions (WTS) for the U.S. Department of Energy (DOE), Carlsbad Field Office (CBFO), Carlsbad, New Mexico. Work was supported by the DOE under Contract No. DE-AC04-01AL66444.

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[1] New Mexico Environment Department (NMED), 1999, "Waste Isolation Pilot Plant Hazardous Waste Facility Permit," NM4890139088-TSDF, Santa Fe, New Mexico.
[2] Federal Register, Vol. 63, No. 95, pp. 27354, May 18, 1998.

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Acronyms and Abbreviations

amsl	above mean sea level
bgs	below ground surface
b.p.	before present
CAO	Carlsbad Area Office
CBFO	Carlsbad Field Office
CFI	Closure from initial
CFR	Code of Federal Regulations
CH	contact-handled
cm	centimeter(s)
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
GAR	Geotechnical Analysis Report
GIS	geomechanical instrumentation system
in.	inch(es)
KPa	kilopascal(s)
lb	pound(s)
m	meter(s)
Ma	millions of years
MB	marker bed
MCL	maximum contaminant level
ml/s	milliliters per second
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
OMB	orange marker bed
psi	pound(s) per square inch
SDD	system design descriptions
SNL/NM	Sandia National Laboratories/New Mexico
SPDV	Site Preliminary Design Validation

TDS	total dissolved solids
TRU	transuranic
WID	Westinghouse Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WTS	Westinghouse TRU Solutions LLC
yr	year(s)

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1.0 Introduction

This Geotechnical Analysis Report (GAR) presents and interprets the geotechnical data from the underground excavations at the Waste Isolation Pilot Plant (WIPP). The data, which are obtained as part of a regular monitoring program, are used to characterize conditions, to compare actual performance to the design assumptions, and to evaluate and forecast the performance of the underground excavations during operations.

GARs have been available to the public since 1983. During the Site and Preliminary Design Validation (SPDV) Program, the architect/engineer for the project produced these reports on a quarterly basis to document the geomechanical performance during and immediately after excavation of the underground facility. Since the completion of the construction phase of the project in 1987, the management and operating contractor for the facility has prepared these reports annually. This report describes the performance and condition of selected areas from July 1, 2000, to June 30, 2001. It is divided into ten chapters. The remainder of Chapter 1 provides background information on WIPP, its mission, and the purpose and scope of the geomechanical monitoring program. Chapter 2 describes the local and regional geology of the WIPP site. Chapters 3 and 4 describe the geomechanical instrumentation located in the shafts and shaft stations, present the data collected by that instrumentation, and provide interpretation of these data. Chapters 5, 6, and 7 present the results of geomechanical monitoring in the three main portions of the WIPP underground facility (the access drifts, the Northern Experimental Area, and the Waste Disposal Area). Chapter 8 discusses the results of the Geoscience Program, which include fracture and stratigraphic mapping, borehole and core logging, and borehole observations. Chapter 9 provides an assessment of the hydrologic conditions near the Exhaust Shaft. Chapter 10 summarizes the results of the geomechanical monitoring and compares the current excavation performance to the design requirements.

1.1 Location and Description

WIPP is located in southeastern New Mexico, 26 miles (42 km) east of Carlsbad (Figure 1-1). The surface facilities were built on the flat to gently rolling hills that are characteristic of the Los Medaños area. The underground facility is being excavated approximately 2,150 feet [ft] (655 m) beneath the surface in the Salado Formation. Figure 1-2 shows a plan view of the current underground configuration of WIPP.

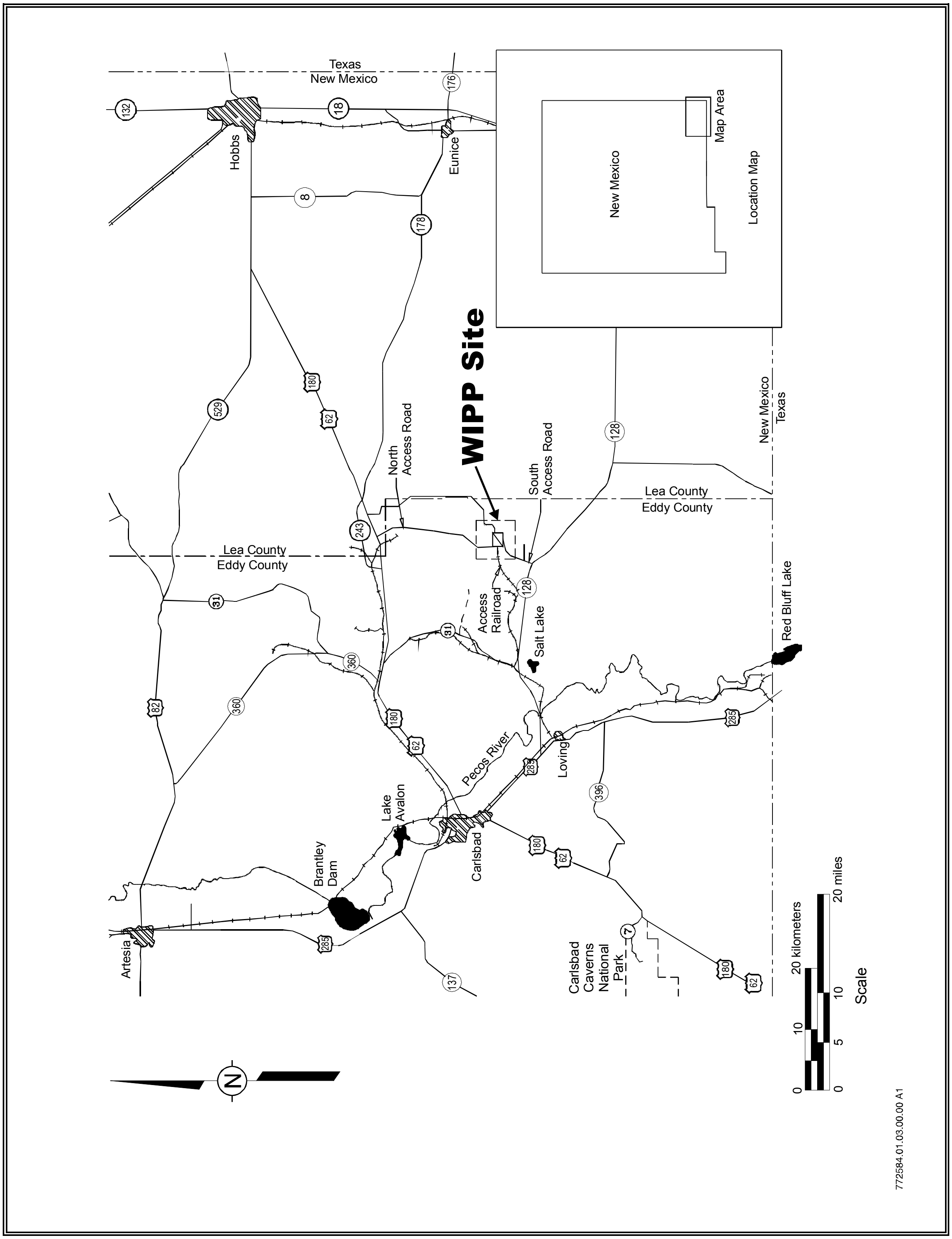

Figure 1-1
WIPP Location

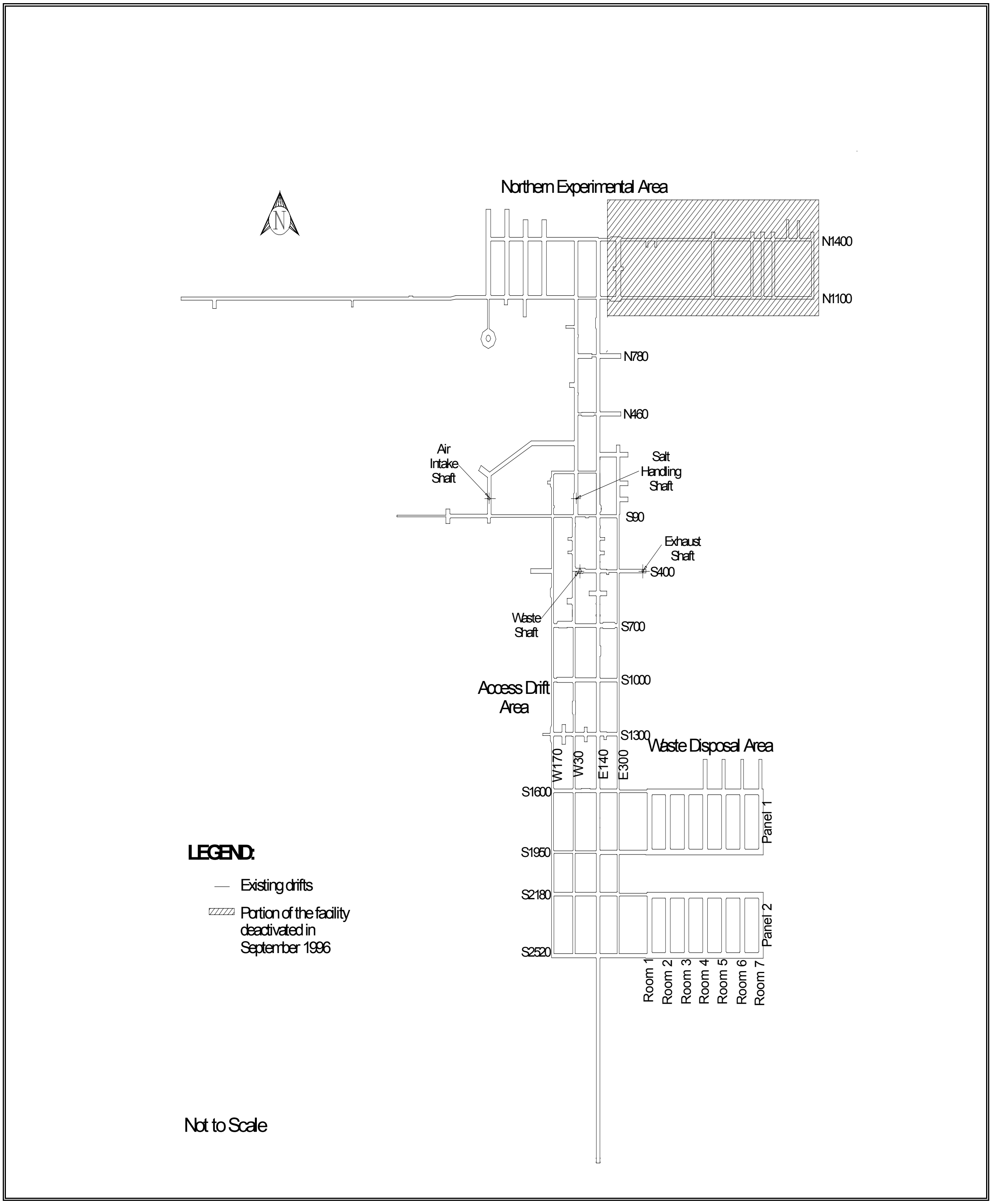

Figure 1-2
Current Underground Configuration

1.2 Mission

In 1979 Congress authorized WIPP (Public Law 96-164) to provide ". . . a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." The WIPP is intended to receive, handle, and permanently dispose of transuranic (TRU) waste and TRU mixed waste. To fulfill this mission, the U.S. Department of Energy (DOE) constructed a full-scale facility to demonstrate both technical and operational principles of the permanent disposal of TRU and TRU mixed wastes. Technical aspects are those concerned with the design, construction, and performance of the subsurface excavations. Operational aspects refer to the receiving, handling, and emplacement of TRU wastes in the facility. The facility was also used for in situ studies and experiments without the use of radioactive waste. These studies and experiments have been completed.

1.3 Development Status

To fulfill its mission, the DOE developed WIPP in a phased manner. The goal of the SPDV phase, begun in 1980, was to characterize the site and obtain in situ geotechnical data from underground excavations in order to determine whether site characteristics and the in situ conditions were suitable for a permanent disposal facility. During this phase, the Salt Handling Shaft, a ventilation shaft, a drift to the southernmost extent of the proposed waste disposal area, a four-room experimental panel, and access drifts were excavated. Surface-based geological and hydrological investigations were also conducted. The data obtained from the SPDV investigations were reported in the “Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program” (DOE, 1983).

Based upon the favorable results of the SPDV investigations, additional activities were initiated in 1983. These included the construction of surface structures, conversion of the ventilation shaft for use as the waste shaft, excavation of the exhaust shaft, development of additional access drifts to the Waste Disposal Area, excavation of the air intake shaft, and excavation of additional experimental rooms to support research and development activities. Geotechnical data acquired during this phase were used to evaluate the performance of the excavations in the context of established design criteria (DOE, 1984). Results of these evaluations were reported in Geotechnical Field Data and Analysis

Reports (DOE, 1985; DOE, 1986a) and were summarized in the Design Validation Final Report (DOE, 1986b).

The Design Validation Final Report concluded that the facility, including waste disposal areas, could be developed and operated to fulfill the long-term mission of WIPP (DOE, 1986b). However, some modifications to the reference design were proposed so that the requirements could be met for the anticipated life of the waste disposal rooms and the demonstration phase while the waste remained retrievable.

The original design for the waste disposal rooms allowed for a relatively short time in which to mine the salt and emplace waste. Each panel, consisting of seven disposal rooms, was scheduled to be mined, filled with waste containers, and closed in fewer than five years. Field studies, as part of the SPDV Program, proved that unsupported openings of a typical disposal room configuration at WIPP would remain stable and safe during the five-year period following excavation, and that closure from creep would not affect the operation of large equipment during that time. The information from these studies validated the design of underground openings to safely accommodate the permanent disposal of waste under routine operating conditions.

Panel 1 was intended to receive waste for an initial operations demonstration and pilot plant phase that was scheduled to start in October 1988. This original plan was to place drums of contact-handled (CH) TRU waste in the disposal rooms for a period of up to 5 years. The waste in the disposal rooms would not be easily accessible, but the option to reenter would be maintained so that the waste could be removed, if required. To maintain roof stability for possible reentry, rock bolts were installed in the rooms.

The operations demonstration was deferred, and the pilot plant phase was modified to use CH TRU waste in bin-scale tests in Room 1, Panel 1. The purpose of this program, referred to as the test phase, was to investigate whether waste disposal at WIPP could be conducted in compliance with environmental standards and regulations. The decision to conduct these bin-scale tests in Room 1, Panel 1, was made in June 1989, when it was anticipated that the initial shipment of waste would be received in 1990. An additional 7 years was required of the room for the on-site bin-scale tests beginning in July 1991. These added requirements led to more stringent criteria for roof support systems. In late 1993, however, the DOE decided to conduct the test phase off site and established 1998 as a new date for first receipt of waste. Delays in obtaining a permit from the New Mexico Environment Department for disposal of the hazardous chemical components of waste postponed the receipt of mixed TRU waste to 1999.

In October 1996, the DOE submitted to the U.S. Environmental Protection Agency (EPA) a compliance certification application in accordance with Title 40 CFR Parts 191 and 194, which addressed the long-term (10,000-year) performance criterion for the disposal system. On May 18, 1998, the EPA published final certification that allows for the receipt of TRU waste at WIPP. Immediately prior to this certification, the DOE Carlsbad Area Office (CAO) completed the WIPP Operational Readiness Review, which was required before the startup of a nuclear waste repository. As a result of the review, the CAO notified the Energy Secretary on April 1, 1998, that WIPP is operationally ready to receive waste. On March 26, 1999, the first shipment of TRU waste was received at the WIPP site from Los Alamos National Laboratory. By the end of June 30, 2001, shipments of TRU waste were being received at the WIPP site from Los Alamos National Laboratory, Savannah River Site, Hanford Site, Rocky Flats Environmental Technology Site, and Idaho National Engineering and Environmental Laboratory.

1.4 Purpose and Scope of Geomechanical Monitoring Program

As specified in the WIPP Hazardous Waste Facility Permit (NMED, 1999), the purpose of the geomechanical monitoring program is to obtain in situ data to support the continuous assessment of the design for underground facilities. Specifically, the program provides for:

- Early detection of conditions that could affect operational safety
- Evaluation of disposal room closure that ensures adequate access
- Guidance for design modifications and remedial actions
- Data for interpreting the behavior of underground openings, in comparison with established design criteria

Polling of the geomechanical instrumentation is performed at least monthly with higher frequency in some areas as deemed necessary. The data taken from the geomechanical instrumentation are evaluated and reported in this Geotechnical Analysis Report. This annual report fulfills the requirements set forth in Section IV.F.1 and Attachment M2, Section M2-5b(2) of the WIPP Hazardous Waste Facility Permit (NMED, 1999), and 40

CFR §191.14, "Assurance Requirements" implemented through the certification criteria, Title 40 CFR Part 194.

The geomechanical instrumentation system (GIS) provides data that are collected, processed, and stored for analysis. The following subsections briefly describe the major components of the GIS.

1.4.1 Instrumentation

Instruments installed for measuring the geomechanical response of the shafts, drifts, and other underground openings include convergence points, convergence meters, extensometers, rock bolt load cells, pressure cells, strain gauges, piezometers, and joint meters. Table 1-1 lists a summary of the geomechanical instrumentation specifications.

Table 1-1
Geomechanical Instrumentation System

Instrument Type	Measures	Range[a]	Resolution[a]
Sonic probe borehole extensometer	Cumulative deformation	0–2 in.	0.001 in.
Convergence points	Cumulative deformation	2–50 ft	0.001 in.
Wire convergence meters	Cumulative deformation	2–50 ft	0.001 in.
Sonic probe convergence meters	Cumulative deformation	2–50 ft	0.001 in.
Embedded strain gauges	Cumulative strain	0–3000 μin./in.	1 μin./in.
Spot-welded strain gauges	Cumulative strain	0–2500 μin./in.	1 μin./in.
Rock bolt load cells	Load	0–50 tons	40 lb
Earth pressure cells	Pressure	0–1000 psi	1 psi
Piezometers	Fluid pressure	0–500 psi	0.5 psi
Joint Meters	Cumulative deformation	0–4 in.	0.001 in.
Vibrating wire borehole extensometer	Cumulative deformation	0–4 in.	0.001 in.
Borehole lateral displacement sensor	Lateral offset	0–3 in.	0.003 in.
Linear potentiometric borehole extensometer	Cumulative deformation	0–6 in.	0.001 in.

[a] Manual read out boxes for the instruments were manufactured to output measurements in English units. Range and resolution measurement units have not been converted to metric units. Measurements from these instruments have been converted for presentation elsewhere in this report.
ft = foot (feet).
in. = inch(es).
μin. = 10^{-6} inch(es).
psi = pound(s) per square inch.
lb = pound(s).

1.4.2 Data Acquisition

The individual geomechanical instruments are read either manually using portable devices or remotely by electronically polling the stations from the surface. Remotely read instruments are connected to one of the data loggers located underground and readings are collected by initiating the appropriate polling routine. Upon completion of a verification process, the data are transferred to a computer database. The manually read devices are taken to the instrument locations underground and the data are recorded on a data sheet and later entered into database files, with the remotely acquired data.

The underground data acquisition system consists of instruments, polling devices, and a communications network. One or more instruments are connected to a polling device. The polling devices are installed in electrical enclosures near the location of the instrument to facilitate queries of each individual instrument. The polling devices are connected by a datalink to a surface computer.

Whether acquired manually or remotely, geomechanical data are entered into the database files of the GIS data processing system. The data processing system consists of computer programs that are used to enter, reduce, and transfer the data to permanent storage files. Additional routines allow access to these permanent storage files for numerical analysis, tabular reporting, and graphical plotting. Copies of the instrumentation database and data plots are available upon request[3].

1.4.3 Data Evaluation

Closure measurements are acquired manually from convergence point anchors and remotely from convergence meters. The plots are presented as ground displacement monitored over time and plotted as either surface displacement versus time or closure versus time.

[3] Instrumentation data and data plots are available in “Geotechnical Analysis Report for July 2000–June 2001 Supporting Data.” This document is available upon request from Westinghouse TRU Solutions. See Foreword and Acknowledgments for details and addresses.

Extensometers provide relative displacement data acquired from sensors installed in a borehole. The displacement is the measure of movement at various depths in the rock strata intercepted by the extensometer borehole. Displacement is measured relative to a fixed point. Extensometers consist of rods that are anchored in a borehole at various depths. The deepest anchor is fixed in what is assumed to be undisturbed ground and is used as the reference point. Typically, the plots will show greater relative ground movement near the collar (i.e., the opening of the hole).

The displacement rate is calculated as follows:

$$\frac{\text{reading at day 2} - \text{reading at day 1}}{(\text{date 2} - \text{date 1}) \times 365.25}$$

Rock bolt load cells are used to determine the bolt loading. Plots show load versus time for each instrumented bolt.

Earth pressure cells and strain gauges are used to determine the stresses and deformations in and around the shaft liners, and data are depicted in time-based plots. These instruments monitor stress in the shaft lining systems.

Piezometers used to measure the gauge pressure of groundwater are installed in the shafts at varying elevations to monitor the hydraulic head acting on the shaft liners. Data from piezometers are plotted as pressure versus time.

Joint meters, installed perpendicular to a crack monitor, the displacement of the crack with time. Data from these are typically presented as displacement versus time.

1.4.4 Data Errors

As described above, GIS data are processed through a comprehensive database management system. Whether acquired manually or remotely, GIS data are processed and permanently stored according to approved procedures. On occasion, erroneous readings can occur. There are several possible explanations for erroneous readings including the following:

- The measuring device was misread.
- The reading was recorded incorrectly.
- The measuring device was not functioning within specifications.

When a reading is believed to be erroneous, an immediate evaluation of the previous readings is performed, and a second reading is collected. If the second reading falls in line with the instrument trend, the first reading is discarded and the second reading is entered in the database. If the second reading and subsequent readings remain out of the instrument trend, the ground conditions in the vicinity of the instrument are assessed to determine the reason for the discrepancy. In addition, reading frequency may be increased. This process to correct erroneous readings is documented and filed for future reference.

2.0 Geology

This chapter provides a summary of the stratigraphy of the WIPP region and the facility stratigraphy. Readers desiring further geologic information may consult the "Geological Characterization Report, WIPP Site, Southeastern New Mexico" (Powers et al., 1978). This report was developed as a source document on the geology of the WIPP site for individuals, groups, or agencies seeking basic information on geologic history, hydrology, geochemistry, or detailed information, such as physical and chemical properties of repository rocks. A more recent survey of WIPP stratigraphy is included in Holt and Powers (1990).

2.1 Regional Stratigraphy

The stratigraphy in the vicinity of the WIPP site includes rocks and sediments of Permian (286 to 245 million years ago [Ma]), Triassic (245 to 208 Ma), and Quaternary (1.6 Ma to present) ages. The generalized descriptions of formations provided in this section are given in order of deposition (oldest to youngest), beginning with the Castile Formation (Figure 2-1).

The Permian system in the United States is divided into four series. The last of these, the Ochoan Series, contains the host rock in which the WIPP facility is located. The Ochoan Series is of mostly marine origin and consists of four formations: three evaporite formations (the Castile, the Salado, and the Rustler) and one redbed formation (the Dewey Lake). The Ochoan evaporites overlie marine limestones and sandstones of the Guadalupian Series (Delaware Mountain Group). The younger redbeds represent a transition from the lower evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. Fluvial deposits of the Triassic and Quaternary periods complete the stratigraphic column.

2.1.1 Castile Formation

The Castile Formation, lowermost of the four Ochoan formations, is approximately 1,250-ft (380 m) thick in the WIPP vicinity. Lithologically, the Castile is the least complex of the evaporite formations and is composed chiefly of interbedded anhydrite and halite, with limestone present in minor amounts.

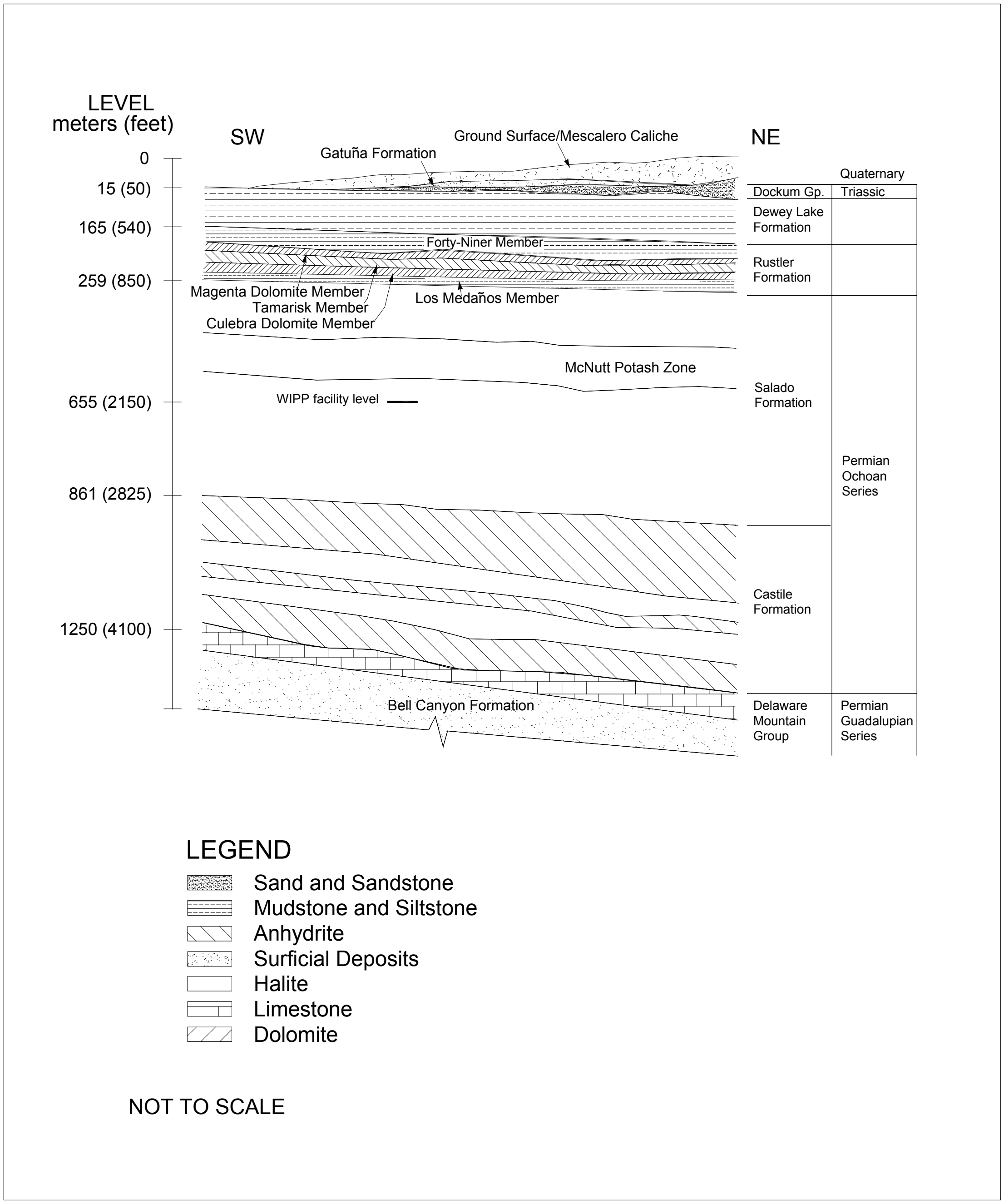

Figure 2-1
Regional Geology

2.1.2 Salado Formation

The Salado Formation comprises nearly 2,000-ft (610 m) of evaporites (primarily halite). The formation is subdivided into three informal members, the unnamed lower member, the McNutt potash zone, and the unnamed upper member. Each member contains similar amounts of halite, anhydrite, and polyhalite and is differentiated on the basis of soluble potassium and magnesium-bearing minerals. The WIPP disposal horizon is located within the unnamed lower member, 2,150-ft (655 m) below the surface.

2.1.3 Rustler Formation

The Rustler Formation is the uppermost of the three Ochoan evaporite formations and contains the largest proportion of clastic material of the three. The Rustler is subdivided into five members as follows (from the base):The Los Medanos Member, the Culebra Dolomite Member, the Tamarisk Member, the Magenta Dolomite Member, and the Forty-niner Member.

In the vicinity of the WIPP site the Rustler is about 310-ft (95 m) thick and thickens to the east. The lower portion (Los Medanos Member) contains primarily fine sandstone to mudstone with lesser amounts of anhydrite, polyhalite, and halite. Bedded and burrowed siliciclastic sedimentary rocks with cross-bedding and fossil remains signify the transition from the strongly evaporitic environments of the Salado to the brackish lagoonal environments of the Rustler (Holt and Powers, 1990).

The upper portion of the Rustler contains interbeds of anhydrite, dolomite, and mudstone. The Culebra Dolomite member is generally brown, finely crystalline and locally argillaceous. The Culebra contains rare to abundant vugs with variable gypsum and anhydrite filling and is the most transmissive hydrologic unit within the Rustler. The Tamarisk Member consists of lower and upper sulfate units separated by a unit that varies laterally from mudstone to mainly halite. The Magenta Dolomite Member is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features. The Forty-niner Member is a mudstone that displays sedimentary features and bedding relationships indicating sedimentary transport and deposition on a mudflat. East of the site area, halite correlates with the mudstone. The Culebra and Magenta Dolomite members are persistent and serve as important marker units.

2.1.4 Dewey Lake Redbeds

The Dewey Lake Redbeds are the uppermost of the Ochoan Series formations in the WIPP vicinity. Within the series, the Dewey Lake represents a transition from the lower marine-influenced evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. The redbeds, about 475-ft (145 m) thick, consist of predominantly reddish-brown interbedded fine-grained sandstone, siltstone, and claystone. The formation is differentiated from other formations by its lithology and distinctive color (both of which are remarkably uniform), and sedimentary structures, including horizontal- and cross-laminae and ripple marks. The redbeds also contain locally abundant greenish-gray reduction spots and gypsum-filled fractures. The formation thickens from west to east due to eastward dips and erosion to the west.

2.1.5 Dockum Group

The Dockum Group consists of fine-grained floodplain sediments and coarse alluvial debris of Triassic age. At the WIPP site, the Dockum Group pinches out near the center of the site and thickens eastward as an erosional wedge. Local subdivisions of the Dockum Group are the Santa Rosa Sandstone and the Chinle Formation; however, only the Santa Rosa occurs in the vicinity of the site. The Santa Rosa consists primarily of poorly sorted sandstone with conglomerate lenses and thin mudstone partings and contains impressions and remnants of fossils. These rocks have more variegated hues than the underlying uniformly colored Dewey Lake.

2.1.6 Gatuña Formation, Mescalero Caliche, and Surficial Sediments

Quaternary Period deposits include the Gatuña Formation, Mescalero Caliche, and surficial sediments. The Gatuña Formation (ranging in age from approximately 13 Ma to 600,000 years before present [b.p.] [Powers and Holt, 1993]) is a stream-laid deposit overlying the Dockum Group in the WIPP vicinity. At the site center the formation consists of about 13-ft (4 m) of poorly consolidated sand, gravel, and silty clay. The Gatuña Formation is light red and mottled with dark stains. The unit contains abundant calcium carbonate but is poorly cemented. Sedimentary structures are abundant (Powers and Holt, 1993, 1995).

The Mescalero Caliche (approximately 500,000 years b.p.) is about 4 ft (1.2 m) thick in the WIPP vicinity. The Mescalero is a hard, resistant soil horizon that lies beneath a cover of wind-blown sand. The horizon is petrocalcic, or very strongly cemented with calcium carbonate. Petrocalcic horizons form slowly beneath a stable landscape at the average depth of infiltration of soil moisture and are an indicator of stability and integrity of the land surface. Many of the surface buildings at WIPP are founded on top of the Mescalero Caliche.

Surficial sediments include sandy soils developed from eolian material and active dune areas. The Berino Series (a soil type) covers about 50 percent of the site and consists of deep sandy soils that developed from wind-worked material of mixed origin. Based on sample analyses, the Berino soil from the WIPP site formed 330,000 ± 75,000 years ago.

2.2 Underground Facility Stratigraphy

The WIPP disposal horizon lies in the approximate center of the Salado Formation. The Salado was deposited in a shallow saline lagoon environment, which progressed through numerous inundation and desiccation cycles that are reflected in the formation. An "ideal" cycle progresses upward as follows: a basal layer consisting predominantly of claystone, followed by a layer of sulfate, which is in turn followed by a layer of halite. The entire sequence is capped by a bed of argillaceous (clay-rich) halite accumulated during a period of mainly subaerial exposure.

A regional system used for numbering the more significant sulfate beds within the Salado designates these beds as marker beds (MB) 100 (near the top of the formation) to MB144 (near the base). The repository's experimental area and disposal area horizons are located between MB138 and MB139 (Figure 2-2) within a sequence of laterally continuous depositional cycles as described above. Within this sequence, layers of clay and anhydrite that are locally designated (as shown) can have a significant impact on the geomechanical performance of the excavations. Clay layers provide surfaces along which slip and separation can occur, whereas anhydrite acts as a brittle unit that does not deform plastically.

2.2.1 Disposal Horizon Stratigraphy (Panels 1, 2, 7 and 8)

Most underground excavations are located within the disposal horizon (see Figure 2-2). In this horizon, the Orange Marker Bed (OMB) typically occurs near mid-rib. The OMB is a laterally consistent unit of moderately to light reddish-orange halite, typically about 6 in. (15 cm) thick that is used as a point of reference for disposal area excavation.

MB139 typically lies about 5-ft (1.5 m) below the excavation floor. MB139 is a 20 to 32 in. (50- to 80-cm) thick layer of polyhalitic anhydrite. The top of the anhydrite undulates up to 15 in. (38 cm) while the bottom is subhorizontal and is underlain by clay E. Above MB139 is a unit of halite that terminates at the base of the OMB. Within this unit, polyhalite is locally abundant and decreases upward, while argillaceous material increases upward.

Above the OMB, a thin sequence of argillaceous halite gives way to a thick sequence of clear halite that becomes increasingly argillaceous upward and is capped by clay F. Clay F occurs as a thin layer occasionally interrupted by partings and breaks and is readily visible in the upper ribs of disposal horizon excavations, usually about 24 in. (60 cm) below the roof.

Above clay F, another sequence of halite begins that, as in lower sequences, becomes increasingly argillaceous upward. This sequence terminates at the clay G/Anhydrite “B” interface, about 6.5 ft (2 m) above the roof of most disposal horizon excavations forming the first roof beam. The roof or “back” of some disposal horizon excavations has been excavated to the clay G/Anhydrite “B” interface. Another depositional sequence begins with Anhydrite “B” and progresses upward to the clay H/Anhydrite “A” interface, typically about 13-ft (4 m) above the roof. Where disposal horizon excavations have been trimmed to the clay G/Anhydrite “B” interface (e.g. E140 drift between S1000 and S1950), this sequence between the clay G/Anhydrite “B” interface and the clay H/Anhydrite “A” interface forms the first roof beam.

2.2.2 Disposal Horizon Stratigraphy (Panels 3, 4, 5 and 6)

In this horizon (See Figure 2-3), the OMB typically occurs at or below the floor. MB139 typically lies about 12 feet (3.7 m) below the excavation floor. At the floor level, a thin sequence of argillaceous halite gives way to a thick sequence of clear halite that becomes increasingly argillaceous upward and is capped by clay F. Clay F occurs as a thin layer occasionally interrupted by partings and breaks and is readily visible in the ribs of disposal horizon excavations, usually about 9 ft. (2.7 m) below the roof.

Above clay F, another sequence of halite begins that, as in lower sequences, becomes increasingly argillaceous upward. This sequence terminates at the clay G/Anhydrite “B” interface, which is the new back.

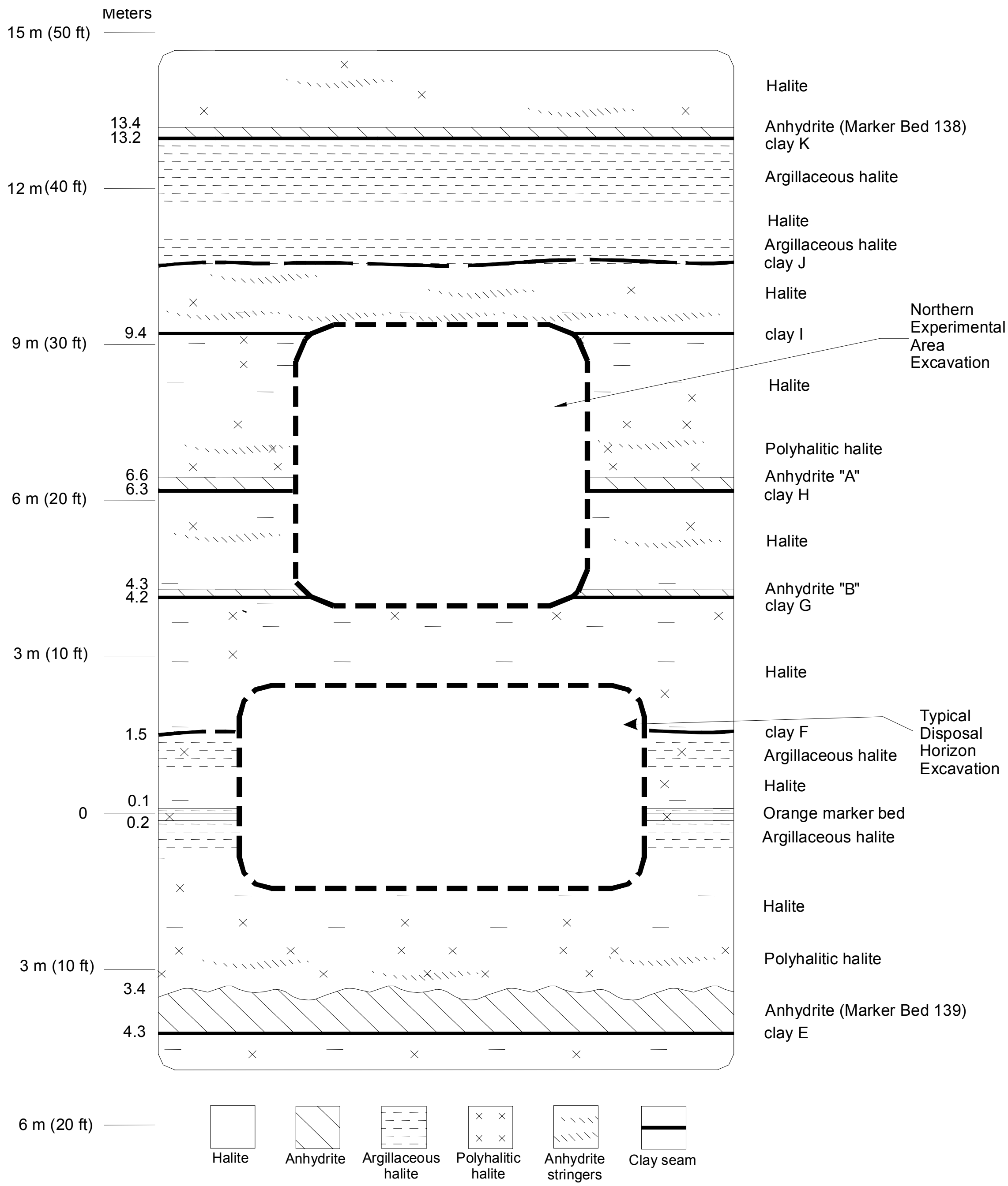

Figure 2-2
Repository Level Stratigraphy (Panels 1, 2, 7 and 8)

2.2.3 Experimental Area Stratigraphy

Some experimental excavations located in the eastern wing of the Northern Experimental Area (deactivated and closed during this reporting period) lie at a higher stratigraphic level than the disposal excavations. These excavations typically have floors excavated at Anhydrite "B." As in the lower units, the halite intervals between the clay seams/anhydrite beds contain relatively pure halite that becomes increasingly argillaceous upward. Above clay I, two more halite intervals complete the underground facility stratigraphy. Clay J, at the top of the first of these intervals, may occur as a distinct seam or merely an argillaceous zone. Clay K tops the second interval and is overlain by anhydrite MB138.

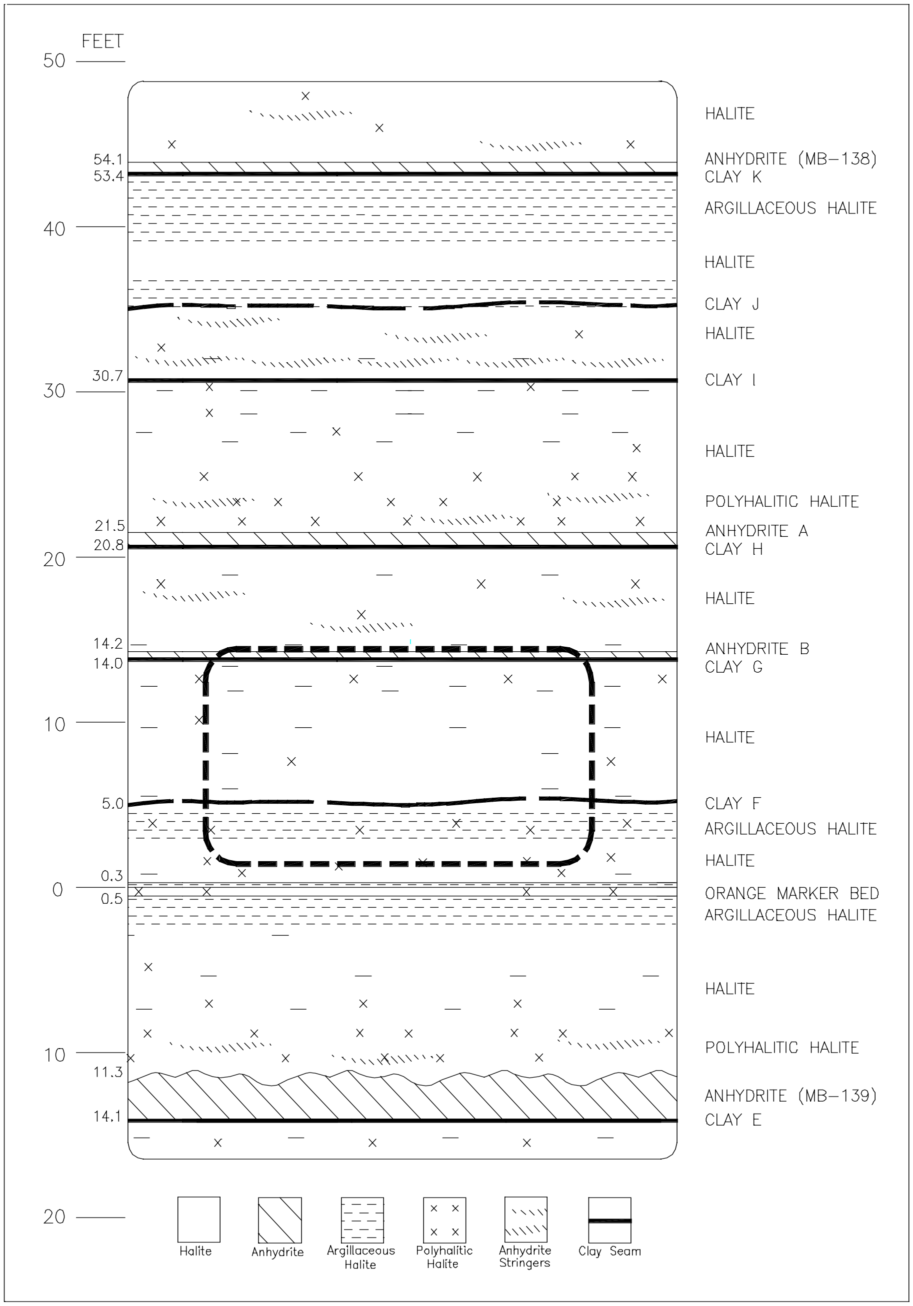

Figure 2-3
Repository Level Stratigraphy (Panels 3, 4, 5 and 6)

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3.0 Performance of Shafts and Keys

Four shafts connect the surface with the WIPP underground facility. The four shafts are the Salt Handling Shaft which is primarily used for removing excavated salt from the underground; the Waste Shaft which is the primary shaft for transporting men and materials between the surface and the underground and is used for transporting the transuranic waste to the underground disposal area; the Exhaust Shaft used to exhaust the ventilation air from the underground; and the Air Intake Shaft which is the primary source of fresh air ventilation to the underground. This chapter describes the geomechanical performance of these shafts.

There are currently no plans to replace failed instrumentation installed in any of the shafts. The project currently has a good understanding of the expected movements in the shafts. The monitoring results, up to the point of instrument failure, did not indicate any unusual shaft movements or displacements. Continued periodic visual inspections confirm the expected shaft performance and provide necessary observations to evaluate shaft performance. It is anticipated that replacement of the failed instrumentation will not provide significant additional information.

3.1 Salt Handling Shaft

The first construction activity undertaken during the SPDV Program was the excavation of the Exploratory Shaft. This shaft was subsequently referred to as the Construction and Salt Handling Shaft and is currently designated the Salt Handling Shaft (see Figure 1-2). The shaft was drilled from July 4 to October 24, 1981, and geologic mapping was conducted in the spring of 1982 (DOE, 1983). Figure 3-1 presents the stratigraphy at the Salt Handling Shaft.

The Salt Handling Shaft is lined with steel casing and has a 10-ft (3-m) inside diameter from the ground surface to the shaft key at a depth of 846-ft (258 m). The steel liner has a thickness of 0.62 in. (1.6 cm) at the top, increasing with depth to a thickness of 1.5 in. (3.8 cm), including external stiffener rings, at the key. Cement grout is placed between the liner and rock face. The 10-ft (3-m) diameter extends through the concrete shaft key to a depth of 880-ft (268 m). The shaft key is a 37.5 ft - (11.4 m -) long reinforced-concrete structure at the base of the steel liner. The shaft from the key to the bottom of the shaft, at a depth of 2,298-ft (700 m), has a nominal diameter of 12-ft (4 m). Wire mesh anchored by rock bolts is installed in this portion as a safety screen to contain rock fragments that may become detached. The shaft extends approximately 140-ft (43 m) below the facility horizon in order to accommodate the skip loading equipment and to act as a sump.

3.1.1 Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections. These inspections are performed principally to assess the condition of the hoisting and mechanical systems, but they also include examining the shaft walls for water seepage, loose rock, or sloughing. The visual shaft inspections during this reporting period found that the Salt Handling Shaft was in satisfactory condition. No ground control activities were required in the Salt Handling Shaft during this reporting period.

3.1.2 Instrumentation

Geomechanical instruments (extensometers, piezometers, and radial convergence points) were installed at various levels in the Salt Handling Shaft during April and July of 1982 (Figure 3-2). In the shaft key, instruments included strain gages, pressure cells, and piezometers (Figure 3-3).

Currently, there are no extensometers that remain functional in the Salt Handling Shaft.

All 12 piezometers continue to provide data. The fluid pressures recorded at the end of this reporting period range from approximately 80 pounds per square in. (psi) (551 kilopascals [KPa]) at the 580-ft (177-m) level in the Forty-niner Member to over 150 psi (1,035 KPa) at the 691-ft (210-m) level in the Tamarisk Member. The recorded pressure of 129-psi (889 KPa) at the Magenta Dolomite Member represents a 42 percent decrease over the recorded pressure in the same location at the end of the previous reporting period. The pressure is still within the design restraints for the shaft liner and the pressure will continue to be monitored on a regular basis.

Four earth pressure cells were installed in the key section of the Salt Handling Shaft during concrete emplacement at the 860-ft (262-m) level. These instruments measure the normal stress between the concrete key and the Salado Formation as the creep effects load on the key structure. Three of the four earth pressure cells continue to provide data, although all three indicate negative pressure. These instruments have essentially indicated no contact pressure since their installation (readings resemble instrument drift at a zero pressure).

The contact pressures recorded by the instruments for this reporting period ranged from 0.5 to -28 psi (3.45 to -193 KPa). Sixteen spot-welded and twenty-four embedment strain gages were installed on and in the shaft key concrete at both the 856.3-ft (261-m) level and at the 862.4-ft (262.9-m) level. The two functioning spot-welded strain gages located at the 856.3-ft (261-m) level reported strains of 514 and 754 microstrain. The strains reported for this reporting period from the 12 embedment strain gages located at the 856.3-ft (261-m) level range from -933 microstrain to 983 microstrain. The strains recorded from both the spot-welded strain gages and the embedment strain gages are very similar to the recorded strains from these instruments at the end of the previous reporting period.

The functioning spot-welded strain gages located at the 862.4-ft (262.9-m) level reported strains ranging from 384 microstrain to 819 microstrain. The 12 embedment strain gages located at the 862.4-ft (262.9-m) level report strains ranging from -383 to 854 microstrain. Again, all strains are very similar to those reported during the previous reporting period.

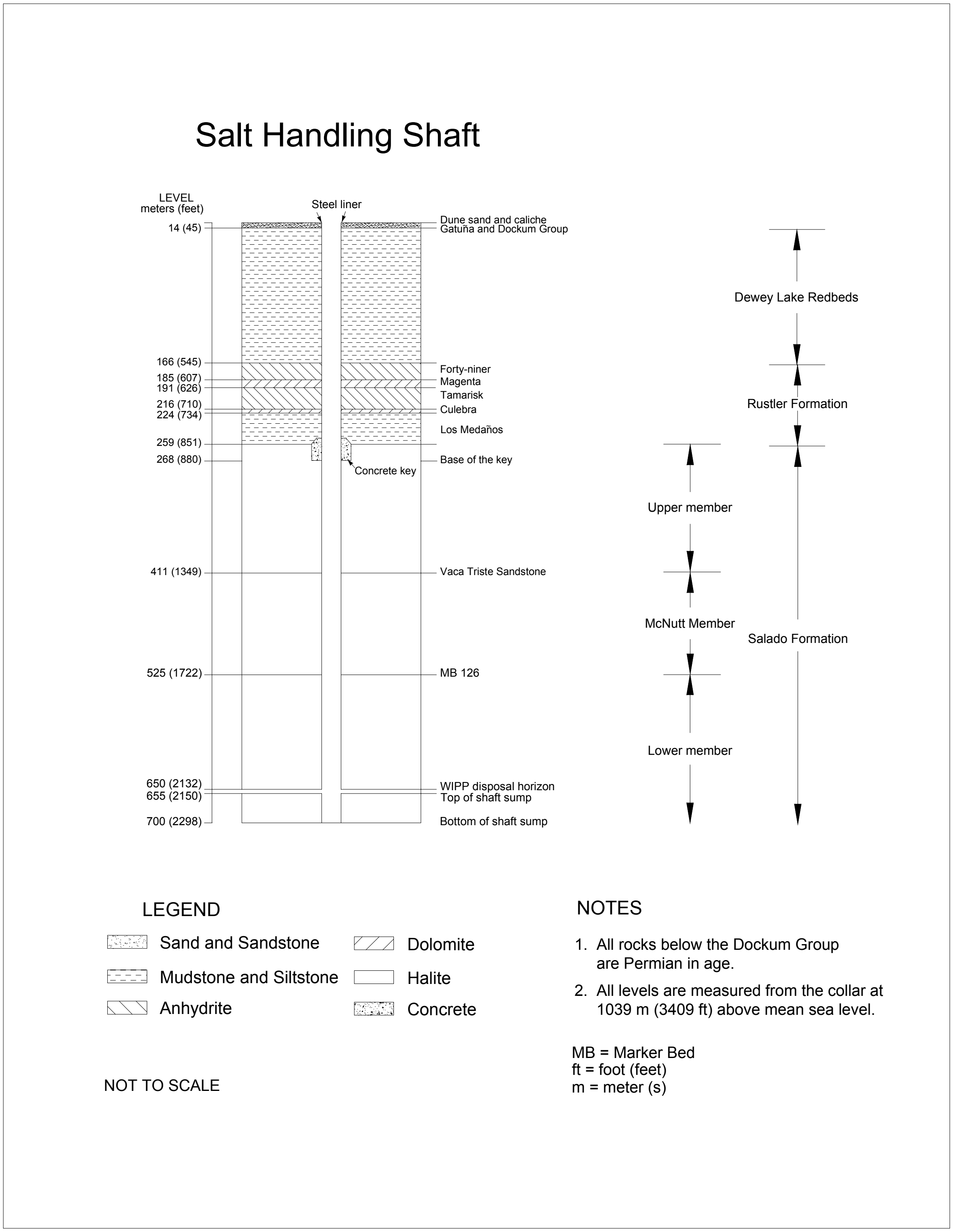


Figure 3-1
Salt Handling Shaft Stratigraphy

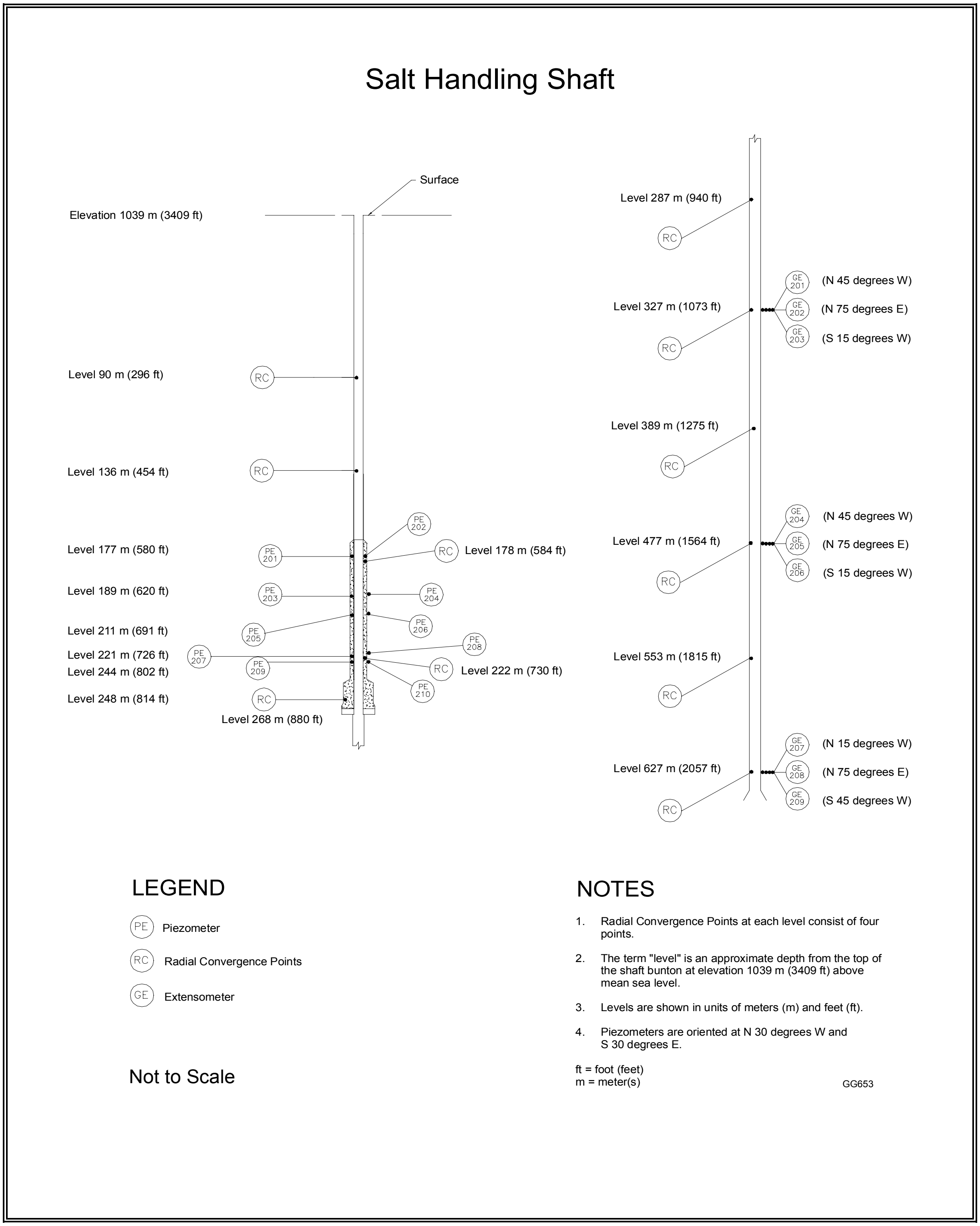


Figure 3-2
Salt Handling Shaft Instrumentation (Without Shaft Key)

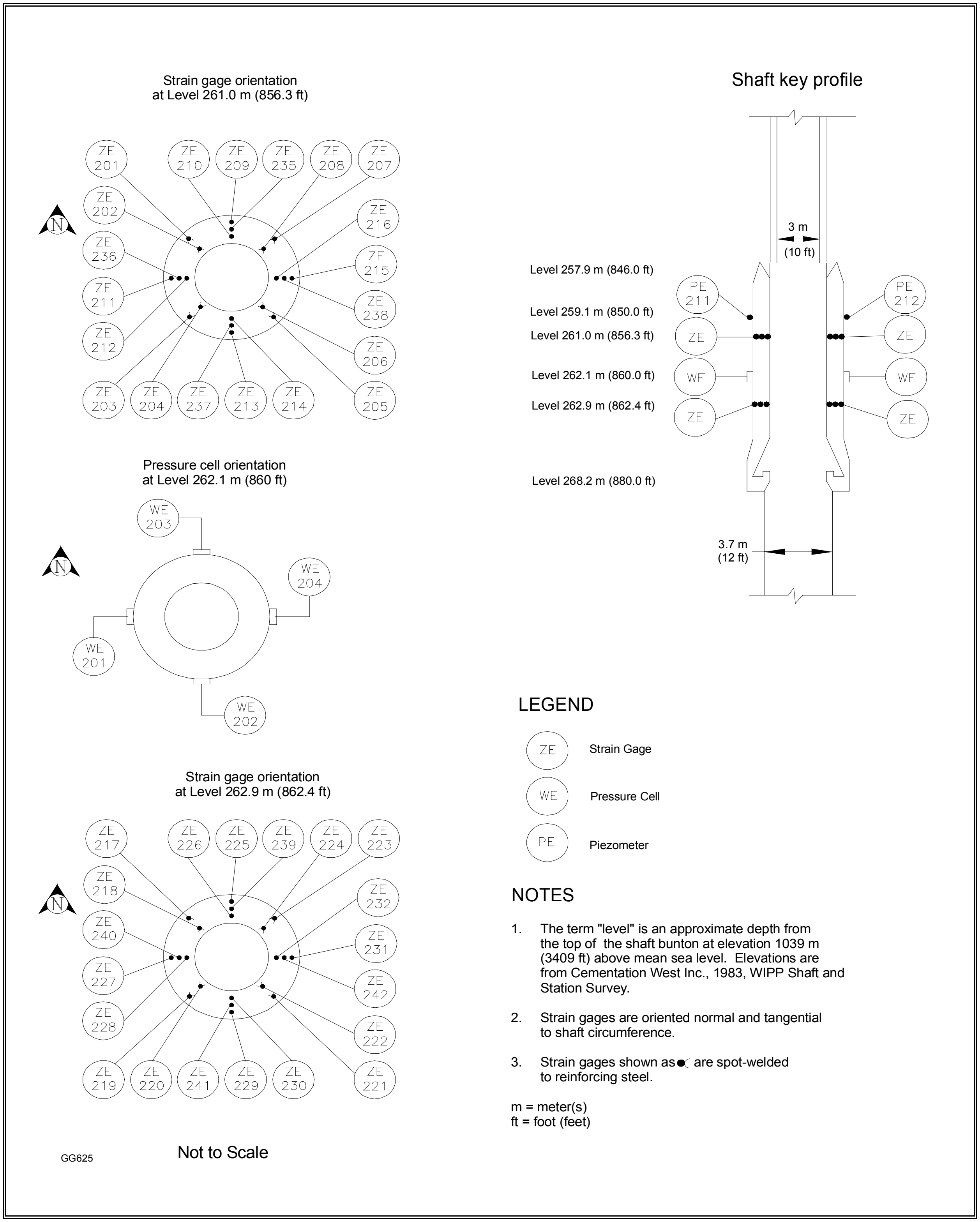


Figure 3-3
Salt Handling Shaft Key Instrumentation

3.2 Waste Shaft

As part of the SPDV Program, a 6-ft (2-m) diameter ventilation shaft, now referred to as the Waste Shaft, was excavated from December 1981 through February 1982. This shaft, in combination with the Salt Handling Shaft, provided a two-shaft underground air circulation system. From October 11, 1983, to June 11, 1984, the shaft was enlarged to a diameter of 20 to 23 ft (6 to 7 m) and lined. Stratigraphic mapping (Figure 3-4) was conducted during shaft enlargement from December 9, 1983, to June 5, 1984 (Holt and Powers, 1984).

The Waste Shaft is lined with nonreinforced concrete and has a 19-ft (6-m) inside diameter from the ground surface to the top of the Waste Shaft key at 837-ft (255 m). Liner thickness increases with depth from 10 in. (25 cm) at the surface to 20 in. (51 cm) at the key. The Waste Shaft key is 63-ft (19 m) long and 4.25-ft (1.3 m) thick and is constructed of reinforced concrete. The bottom of the key is 900-ft (274 m) below the surface. The diameter of the shaft is 20-ft (6 m) at the point below the key and increases to 23-ft (7 m) just above the shaft station. The shaft below the key is lined with wire mesh anchored by rock bolts. The diameter of 23-ft (7 m) extends to a depth of approximately 2,286-ft (697 m) with the shaft sump comprising the lower 128-ft (39 m) of that interval.

3.2.1 Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections. These inspections are performed principally to assess the condition of the hoisting and mechanical systems, but also include observation of the shaft walls for water seepage, loose rock, or sloughing. The visual shaft inspections during this reporting period found that the Waste Shaft was in satisfactory condition. No ground control activities other than routine maintenance were required in the Waste Shaft during this reporting period.

3.2.2 Instrumentation

Extensometers, piezometers, earth pressure cells, and radial convergence points were installed in the Waste Shaft between August 27 and September 10, 1984. Figures 3-5 and 3-6 illustrate the instrumentation configurations in the shaft and shaft key.

Nine multiposition borehole extensometers were installed in arrays at 1,071-ft (326 m), 1,566-ft (477 m), and 2,059-ft (628 m) below the surface as shown in Figure 3-5. Each array consists of three extensometers. Currently, seven out of nine extensometers remain functional. Table 3-1 summarizes information regarding collar displacement measurements from these extensometers.

Table 3-1
Collar Displacement at Waste Shaft Extensometers

Field Tag	Location	Total Displacement (in.)		Total Displacement (in.)		Displacement	Displacement	
		Report Date		Previous Date		2000-2001 Rate	1999-2000 Rate	% Change
31X-GE-00203	1071 level, S15W	05/29/2001	0.192	06/05/2000	0.182	0.010	0.007	42.9%
31X-GE-00204	1566 level, N45W	05/29/2001	0.721	06/05/2000	0.687	0.035	0.034	2.9%
31X-GE-00205	1566 level, N75E	05/29/2001	0.607	06/05/2000	0.575	0.033	0.027	22.2%
31X-GE-00206	1566 level, S15W	05/29/2001	0.729	06/05/2000	0.694	0.036	0.035	2.9%
31X-GE-00207	2059 level, N45W	05/29/2001	1.829	05/01/2000	1.733	0.089	0.080	11.3%
31X-GE-00208	2059 level, N75E	05/29/2001	1.713	06/05/2000	1.640	0.074	0.080	-7.5%
31X-GE-00209	2059 level, S15W	05/29/2001	1.937	06/05/2000	1.852	0.087	0.095	-8.4%

The collar displacements at the level 1,071-ft (326-meter) indicate an annual displacement rate[4] of 0.010 in./yr. (0.025 cm/yr.). This is a relatively slow displacement rate and represents a rate increase of 43 percent when compared to the negligible annual collar displacement rate of 0.007 in./yr. (0.018 cm/yr.) from the previous reporting period. Overall, these displacement rates show a slight percentage increase over the previous reporting period.

[4] Annual displacement rates are calculated as the difference in collar displacement readings from the first reading of the previous reporting period to the final reading of this reporting period divided by the time between those two readings, usually approximately one year.

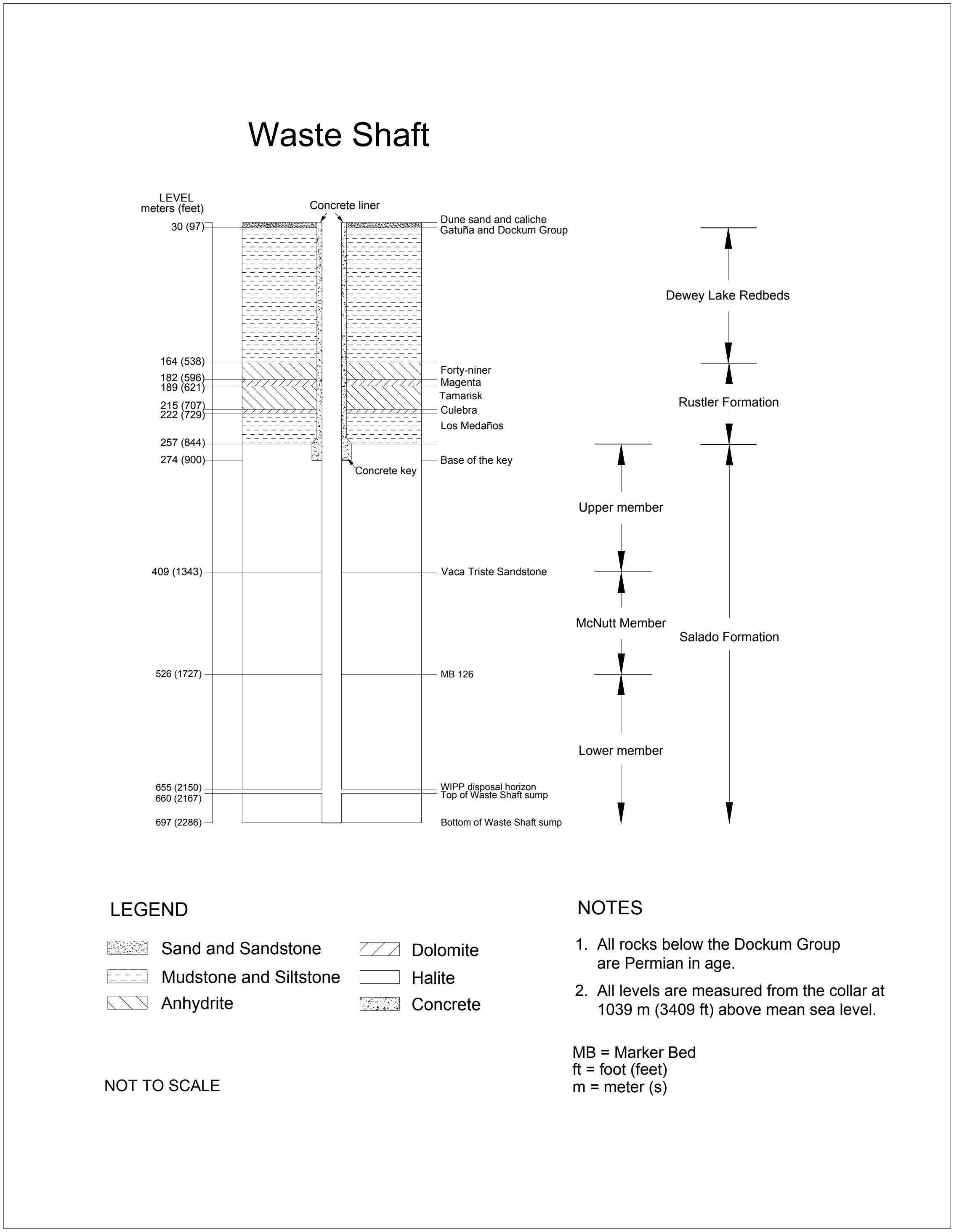


Figure 3-4
Waste Shaft Stratigraphy

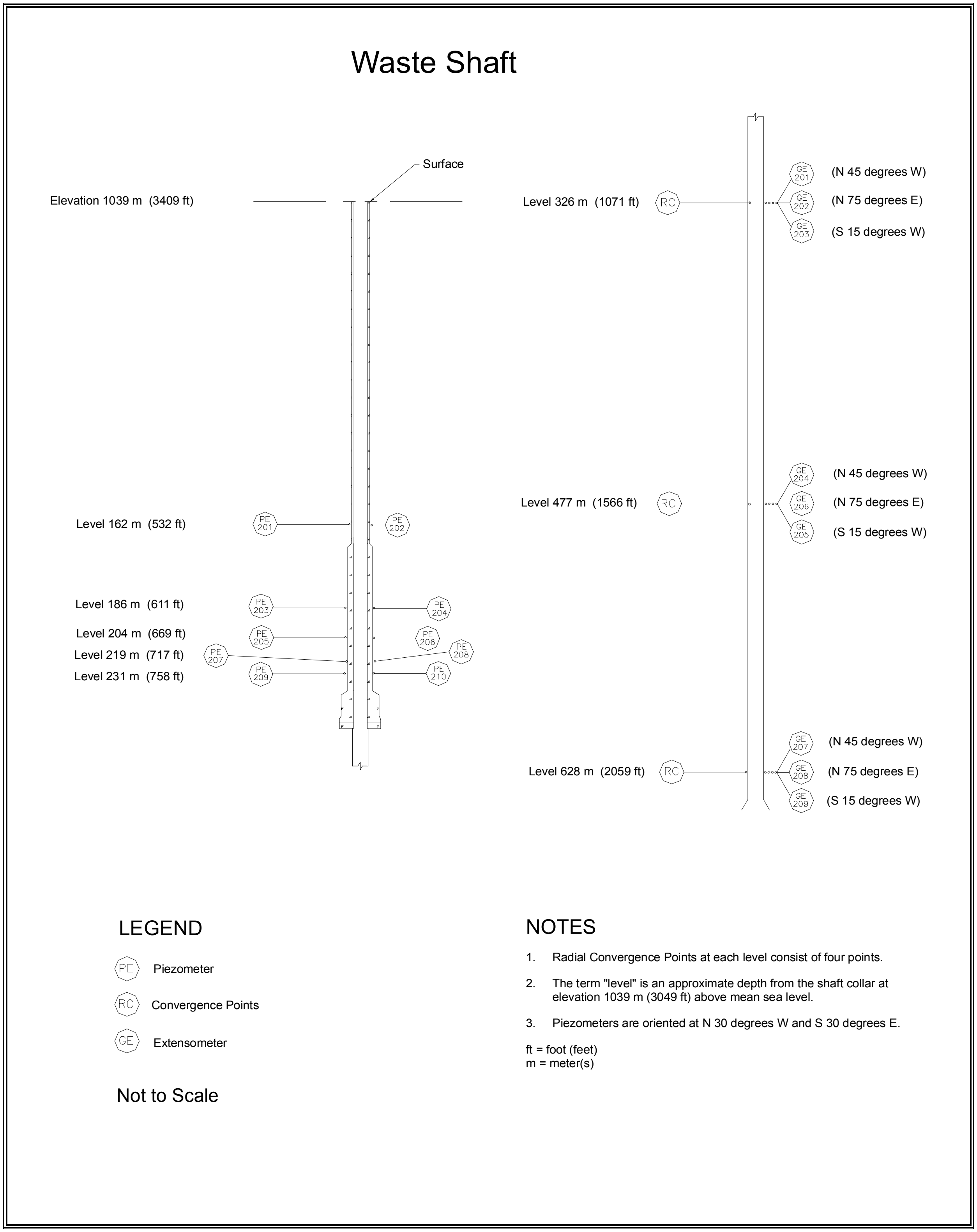


Figure 3-5
Waste Shaft Instrumentation (Without Shaft Key)

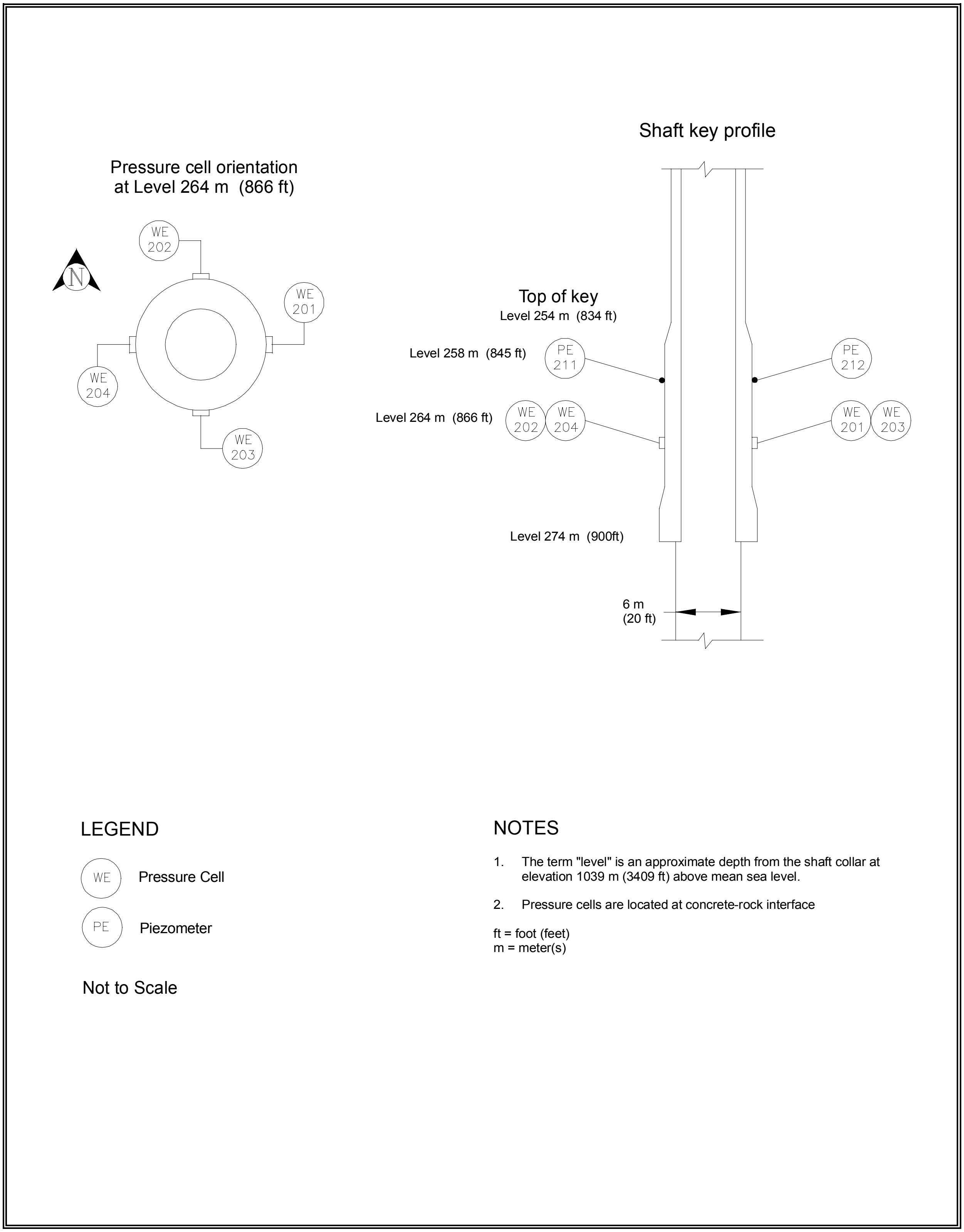


Figure 3-6
Waste Shaft Key Instrumentation

The collar displacement rates at the level 1,566-ft (477-meter) have remained similar relative to the rates from the previous reporting period. The annualized displacement rate for two extensometers has increased by approximately 3 percent, while the remaining extensometer increased by 22 percent. At the 2,059-ft level (628 m) the collar displacement rate varied from an increase of 11 percent for 31X-GE-00207 to a decrease of 8 percent at the other two installations. Again these rates are considered acceptable, as they closely follow the long-term trend. There is no indication of shaft instability from routine inspections.

Twelve piezometers were installed in the lined section of the Waste Shaft on September 7 and 8, 1984, to monitor pressure behind the shaft liner and key section in the shaft. Data continue to be received from all 12 piezometers, although 6 of the 12 report zero or near zero fluid pressure. The recorded positive fluid pressures from the remaining 6 piezometers at the end of the reporting period range from 35 psi (238 KPa) at the Magenta Dolomite Member (611-ft [186 m] depth) up to greater than 147 psi (1,000 KPa) at the level where the shaft intersects the Culebra Dolomite Member (717-ft [218.5-m] depth).

Four earth pressure cells were installed in the key section of the Waste Shaft during concrete emplacement between March 23 and April 3, 1984. These instruments measure the normal stress between the concrete key and the Salado Formation as the salt creep loads the key structure. The contact pressure recorded by these four instruments has remained fairly constant over the past five years. The pressures of record during this reporting period between 96 and 114 psi (655 and 778 KPa).

3.3 Exhaust Shaft

The Exhaust Shaft was drilled from September 22, 1983, to November 29, 1984, to establish a route from the underground facility to the surface for exhaust air. Stratigraphic mapping was conducted from July 16, 1984, to January 18, 1985 (DOE, 1986c). Figure 3-7 illustrates the Exhaust Shaft Stratigraphy.

The Exhaust Shaft is lined with nonreinforced concrete from the surface to the top of the shaft key at a depth of 844-ft (257 m). The liner thickness increases from 10 to 16 in. (25 to 41 cm) over that interval. The Exhaust Shaft key is 63-ft (19 m) long and 3.5-ft (1 m) thick. The shaft diameter below the key is 15-ft (5 m) and the interval below the key is lined with wire mesh anchored by rock bolts. The shaft terminates at the facility horizon, at a depth of approximately 2,150-ft (655 m). There is no excavated shaft sump.

3.3.1 Shaft Observations

Quarterly remote video inspections of the shaft indicate that the shaft is in satisfactory condition. No modifications were made to the shaft during this reporting period.

In March 1995 a scheduled inspection revealed a thin stream of water emerging from the liner into the shaft, at a depth of approximately 80-ft (24 m) below the shaft collar. A program was initiated to investigate the source and extent of the water. Results of ongoing monitoring are presented in Chapter 9.

3.3.2 Instrumentation

The Exhaust Shaft was equipped with geomechanical instrumentation in two stages. Earth pressure cells were installed behind the liner key in November 1984. Piezometers and nine multiposition borehole extensometers were installed during November and December 1985. Figures 3-8 and 3-9 illustrate the instrumentation configuration.

The extensometers at the 1,573-ft (480 m) level indicate annual collar displacement rates ranging from 0.020 to 0.023 in/yr. (0.051 to 0.058 cm/yr.) These rates have not significantly changed from the previous reporting periods. At the 2,066-ft (630 m) level, the annualized collar displacement rates range from 0.062 in/yr. to 0.087 in/yr. (0.157 to 0.221 cm/yr.) These displacements indicate continued deformation into the shaft; however, there is no indication of accelerated movement.

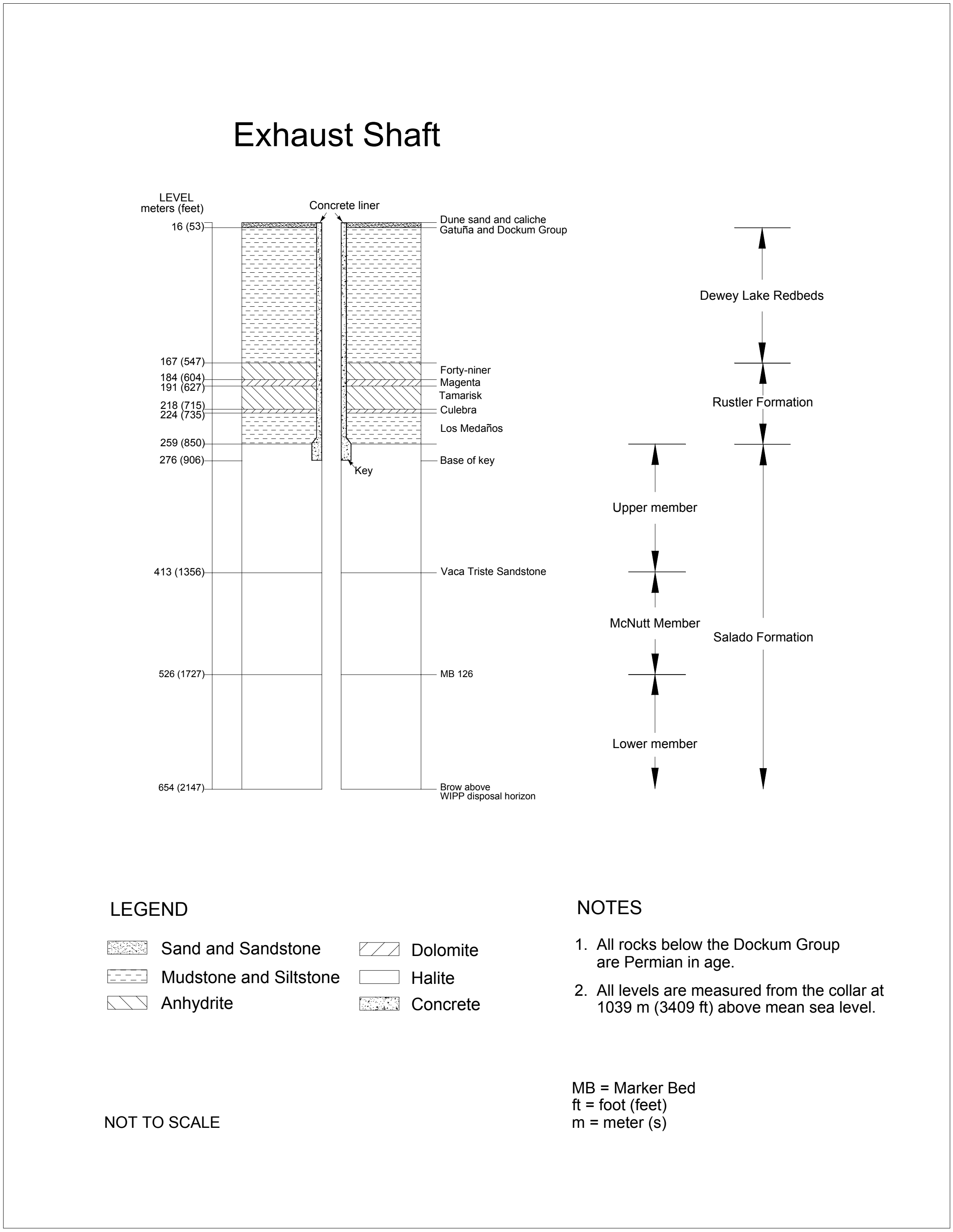


Figure 3-7
Exhaust Shaft Stratigraphy

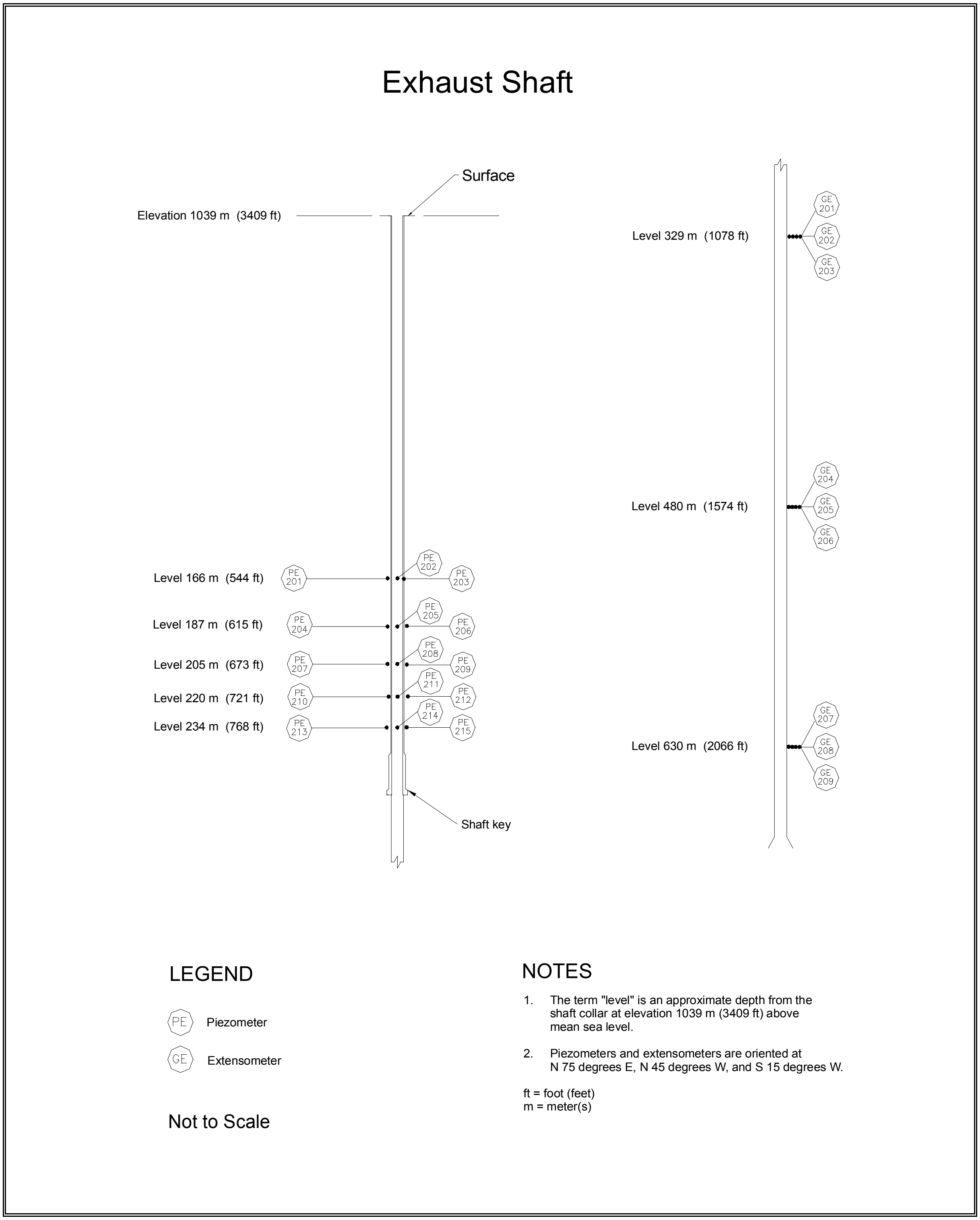
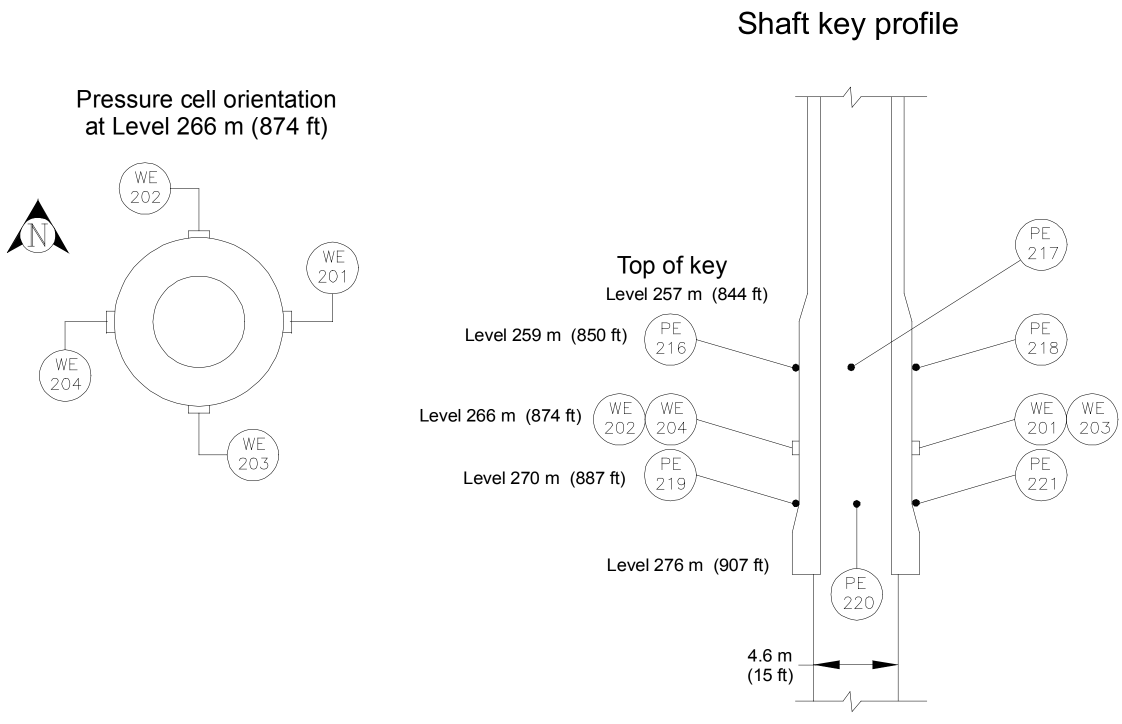


Figure 3-8
Exhaust Shaft Instrumentation (Without Shaft Key)



LEGEND

WE Pressure Cell

PE Piezometer

Not to Scale

NOTES

1. The term "level" is an approximate depth from the shaft collar at elevation 1039 m (3049 ft) above mean sea level.

2. Pressure cells are located at concrete-rock interface and oriented at azimuths of 0 degrees, 90 degrees, 180 degrees, and 270 degrees.

3. Piezometers are oriented at N 75 degrees E, N 45 degrees W, and S 15 degrees W.

ft = foot (feet)
m = meter(s)

Figure 3-9
Exhaust Shaft Key Instrumentation

Thirteen of the twenty-one piezometers installed remain in working condition. The fluid pressure readings from the working piezometers at the end of the reporting period range from -3.7 psi (-25 KPa) at the 544-ft (166-m) level to 140 psi (963 KPa) at both the 721-ft (220-m) level and the 615-ft (187.5-m) level. Maximum pressure readings from the working piezometers during this reporting period were consistent with maximum readings from the previous reporting period with some of the recorded pressures having decreased slightly.

Two earth pressure cells were installed in the key section of the Exhaust Shaft during concrete emplacement. During this reporting period, the pressure cells have indicated a gradual decreasing trend. The maximum-recorded pressures during this period are 46 and 58 psi (314 and 396 KPa).

3.4 Air Intake Shaft

The Air Intake Shaft was drilled from December 4, 1987, to August 31, 1988, to establish a primary route for surface air to enter the repository. Stratigraphic mapping was conducted from September 14, 1988, to November 14, 1989 (Holt and Powers, 1990). Figure 3-10 illustrates the Air Intake Shaft stratigraphy.

The Air Intake Shaft is lined with nonreinforced concrete from the surface to the bottom of the shaft key at a depth of 903-ft (275 m). The Air Intake Shaft key is 81-ft (25 m) long with an inside diameter of 16-ft (5 m). The diameter below the shaft key is 20-ft (6 m), and the shaft is unlined below the key to the facility horizon at a depth of 2,150-ft (655 m). The Air Intake Shaft has no sump.

3.4.1 Shaft Performance

Weekly visual inspections were performed on the Air Intake Shaft during this reporting period and the shaft was found to be in satisfactory condition.

3.4.2 Instrumentation

Sandia National Laboratories/New Mexico (SNL/NM) installed geomechanical instruments in the shaft in 1988. WTS maintains responsibility for the operation of all of the instruments located in the Air Intake Shaft as well as for data acquisition and instrument maintenance. WTS provides the data to SNL/NM for analysis. Data from these instruments are available from SNL/NM by request.

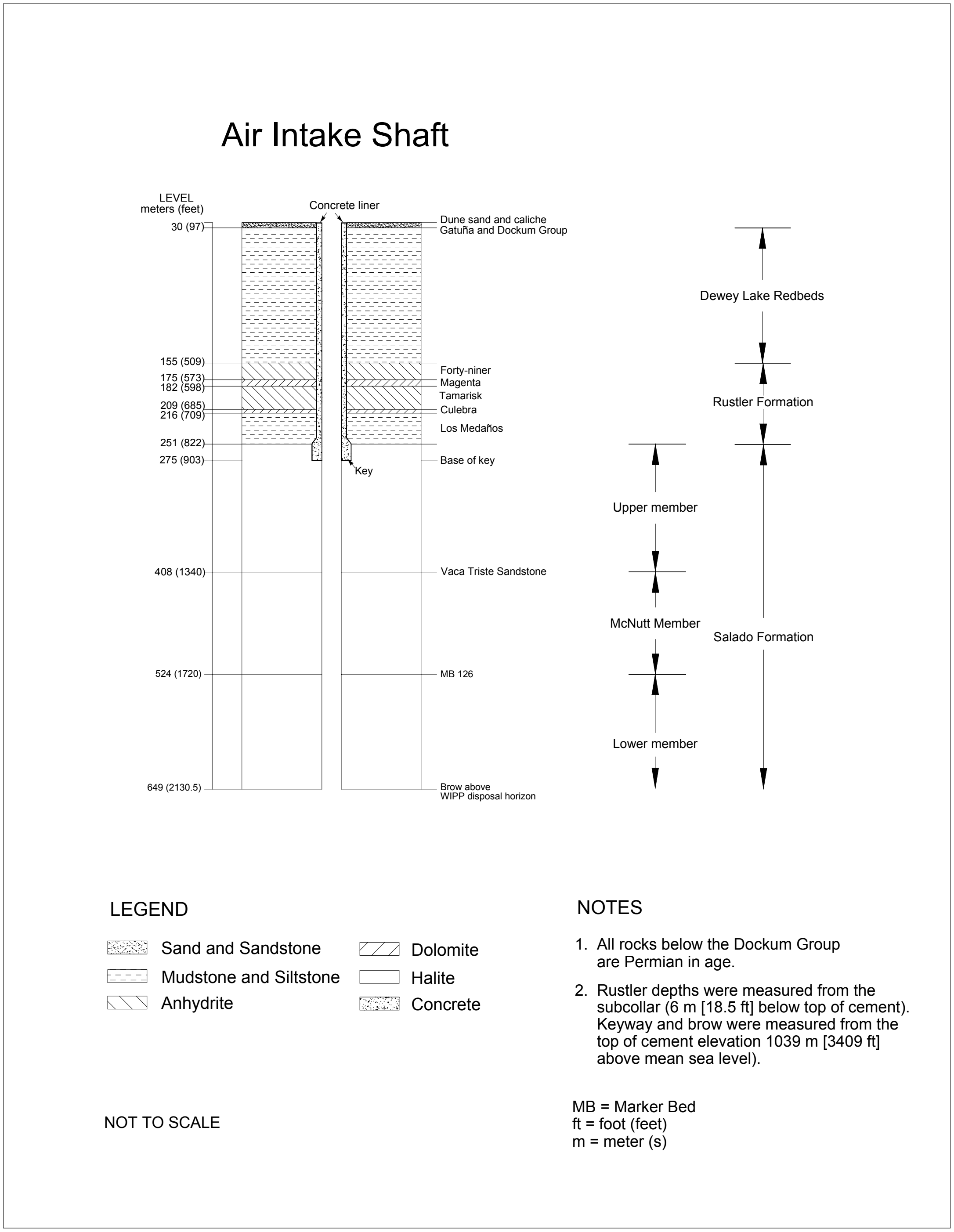


Figure 3-10
Air Intake Shaft Stratigraphy

4.0 Performance of Shaft Stations

This chapter describes the instrumentation and geomechanical performance of the enlarged working areas (called shaft stations) around the intersections of the Salt Handling Shaft, Waste Shaft, and the Air Intake Shaft, with the underground facility. The Exhaust Shaft does not have an enlarged shaft station and therefore, is not included in this chapter.

4.1 Salt Handling Shaft Station

The Salt Handling Shaft Station was excavated between May 2 and June 3, 1982, by drilling and blasting. In 1987 the station was enlarged, removing the roof beam up to Anhydrite “B” between S90 and N20 using a mechanical scaler. In 1995 the remaining roof beam at the north end of the station was also removed up to Anhydrite “B.” The station area south of the shaft is 90 ft (27.5 m) long and 32 to 38 ft (10 to 12 m) wide. The height of the station south of the shaft is 18-ft (5.5 m). The station dimensions north of the shaft are approximately 30 ft (9 m) long, 32 to 35 ft (10 to 11 m) wide, and 18 ft (5.5 m) high. The shaft extends approximately 140-ft (43 m) below the facility horizon in order to accommodate the skip loading equipment and to act as a sump. Figure 4-1 shows a generalized cross section of the station.

4.1.1 Modifications to Excavation and Ground Control Activities

No major modifications were performed in the Salt Handling Station during this reporting period. Ground control was performed as routine maintenance.

4.1.2 Instrumentation

Geomechanical instrumentation was installed in the Salt Handling Shaft Station between June 1982 and February 1983, with subsequent reinstallation of extensometers and convergence points as necessary. Figure 4-2 shows the instrument locations in the Salt Handling Shaft Station before the roof beam was removed in 1987. Affected instruments were either removed, or readings were suspended, prior to mining the roof beam. Figure 4-3 shows the instrument locations after the roof beam was taken down.

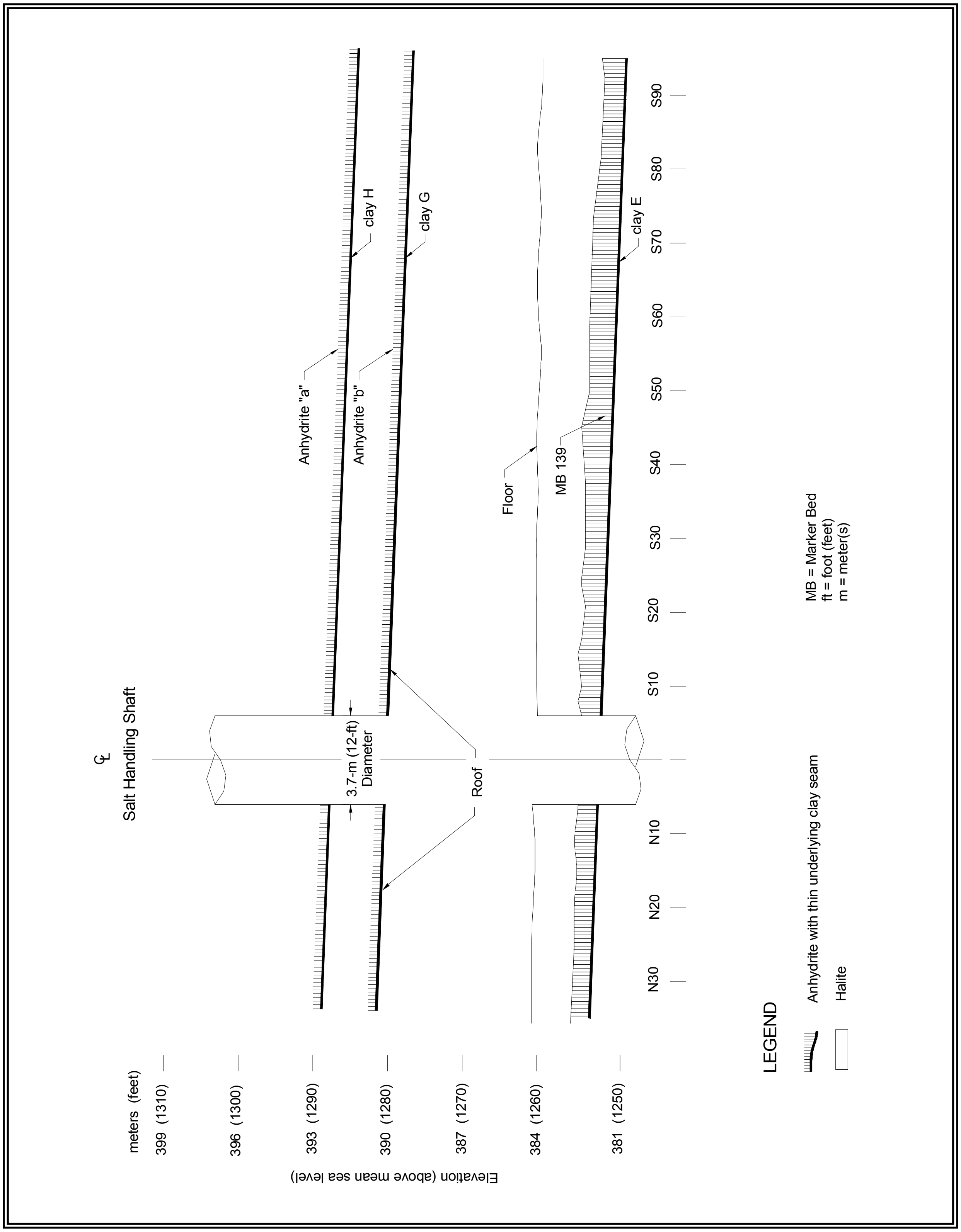


Figure 4-1
Salt Handling Shaft Station Stratigraphy

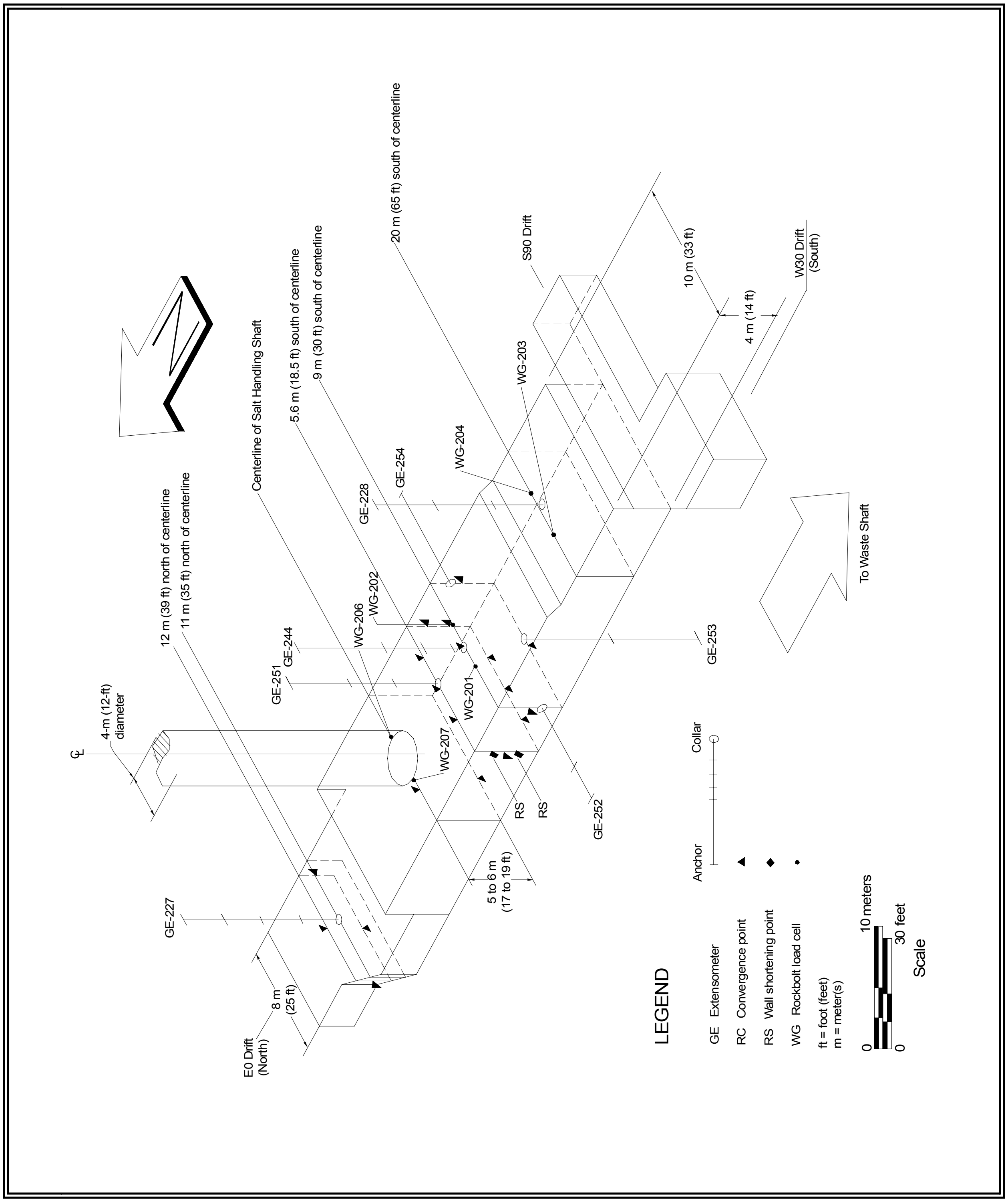


Figure 4-2
Salt Handling Shaft Station Instrumentation Before Roof Beam Excavation

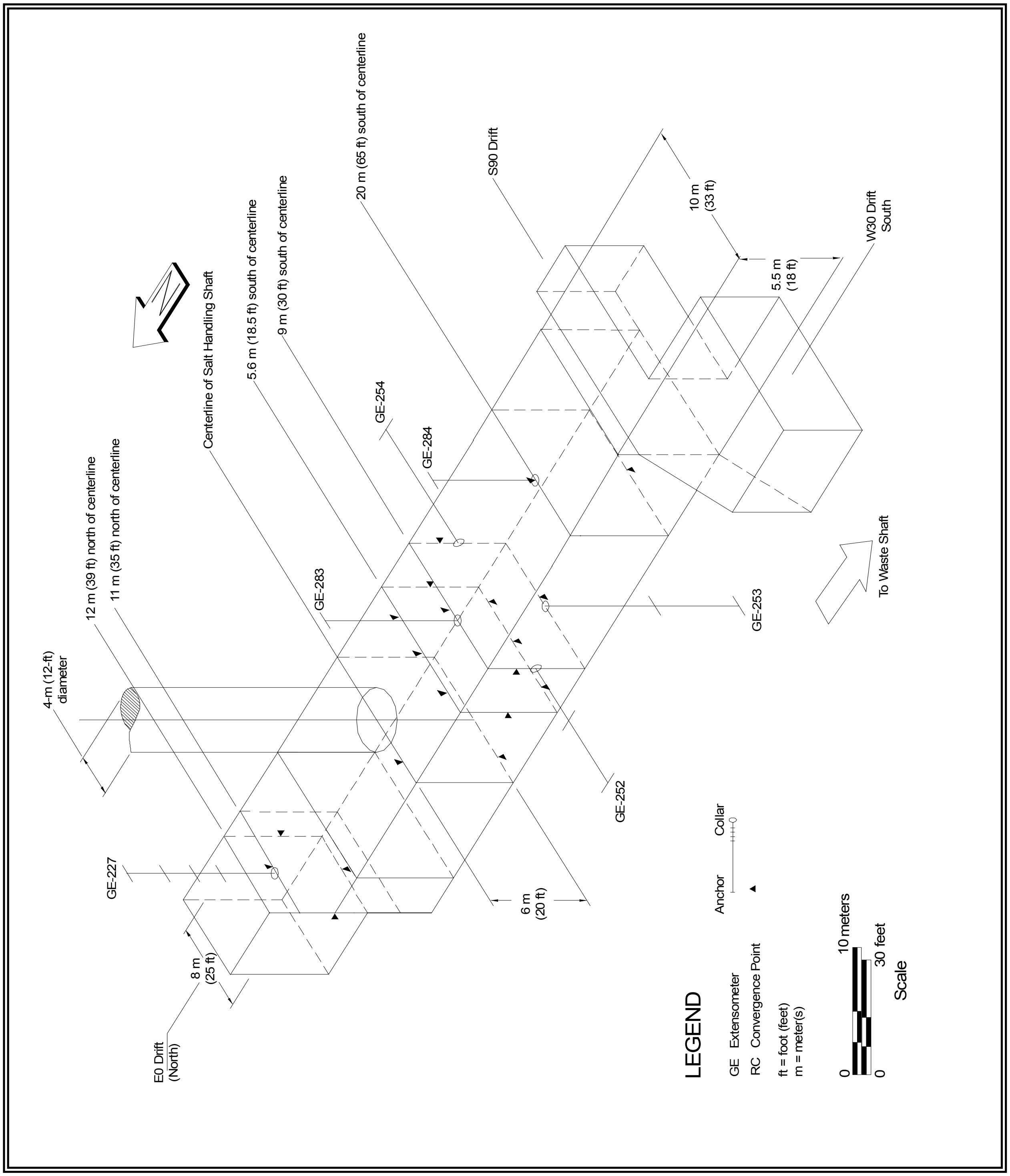


Figure 4-3
Salt Handling Shaft Station Instrumentation After Roof Beam Excavation

There are three extensometers located in the Salt Handling Shaft Station. Due to instrument malfunctions there are no extensometer data for the Salt Handling Shaft Station for this reporting period, however, historical data are maintained for comparative purposes. Five vertical convergence point arrays and one horizontal convergence chord are currently monitored. Table 4-1 summarizes the vertical closure rates in the Salt Handling Shaft Station from July 1999 through June 2001. Salt Handling Shaft Station vertical closure rates have remained relatively consistent compared to previous reporting periods. There has been a slight increase in convergence rates from the previous reporting period.

Table 4-1
Vertical Closure Rates in the Salt Handling Shaft Station

Location		1999-2000 Closure Rate in./yr. (cm/yr.)	2000-2001 Closure Rate in./yr. (cm/yr.)	Percent Rate Change
E0-N39	Drift centerline	2.09 (5.31)	1.89 (4.80)	-9.8
E0-W12	Along west rib	0.86 (2.18)	0.88 (2.24)	1.4
E0-S18	Along east rib	1.63 (4.14)	1.92 (4.88)	17.9
E0-S18	Along west rib	1.13 (2.87)	1.14 (2.90)	1.0
E0-S18	Drift centerline	1.64 (4.17)	1.68 (4.27)	2.2
E0-S30	Drift centerline	1.75 (4.44)	1.77 (4.50)	1.3
E0-S65	Drift centerline	1.35 (3.43)	1.35 (3.43)	0.0

in./yr. = inch(es) per year.
cm/yr. = centimeter(s) per year.

4.2 Waste Shaft Station

The Waste Shaft Station was initially excavated with a continuous miner as a ventilation connection to a 6-ft (2-m) diameter exhaust shaft in November 1982. In 1984, the station was enlarged to a height of 15 to 20 ft (4.5 to 6 m) and a width of 20 to 30 ft (6 to 9 m). The station is approximately 150-ft (46 m) long. In 1988 the station walls were trimmed and concrete was placed on the floor. Since 1988, the Waste Shaft Station has undergone three major floor renovations. A 53-ft (16 m) long section of the reinforced concrete was removed in February 1991 and in 1995 an additional 30-ft (9 m) section was removed. The most recent floor maintenance included removal of the remaining reinforced concrete section, trimming of the floor, and reinstallation of the rails supported by segmented concrete panels on a crushed rock backfill. Figure 4-4 shows a cross section of the Waste Shaft Station.

4.2.1 Modifications to Excavation and Ground Control Activities

There were no major modifications to this station during this reporting period. Ground control activities performed in the Waste Shaft Station during this reporting period consisted of routine rib maintenance and the routine replacement of failed rock bolts.

4.2.2 Instrumentation

Instruments were initially installed in the Waste Shaft Station between November 12 and December 2, 1982. Figure 4-5 illustrates the instrument locations in the Waste Shaft Station before it was enlarged in 1988. Figure 4-6 illustrates the locations after enlargement. There are three extensometers in the roof of the Waste Shaft Station (located at W30, E35, and E140) that are currently being monitored. In addition, horizontal convergence is being monitored at E30 and E90.

Table 4-2 summarizes the history of the roof extensometers in the Waste Shaft Station. The extensometers, 51X-GE-00268 and 51X-GE-00279, remain in good working condition and the data indicate a relatively steady displacement rate. Extensometer 51X-GE-00277 is no longer functional due to damage. The annual displacement rate calculated for extensometer 51X-GE-00279, located in S400 drift at E140 is slightly lower than the rate calculated for the previous reporting period. However, the data trend at this installation is consistent with historic displacement rates for this instrument.

Table 4-3 summarizes the annual closure rates calculated from convergence point data for this reporting period. The data indicate a slight decrease in horizontal closure rates at E30 and E90 of 3.0 and 0.3 percent, respectively, relative to the previous annual closure rates.

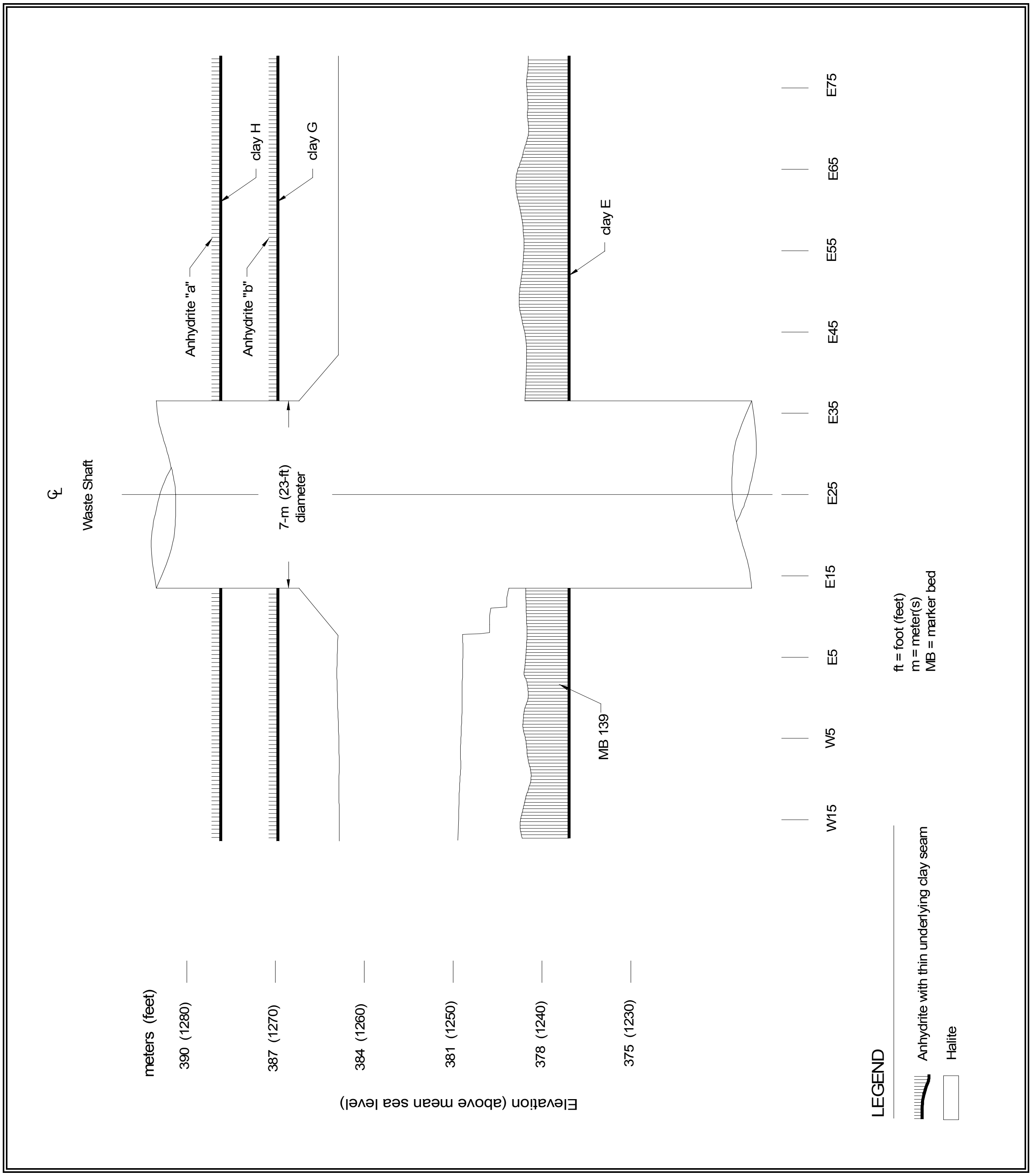


Figure 4-4
Waste Shaft Station Stratigraphy

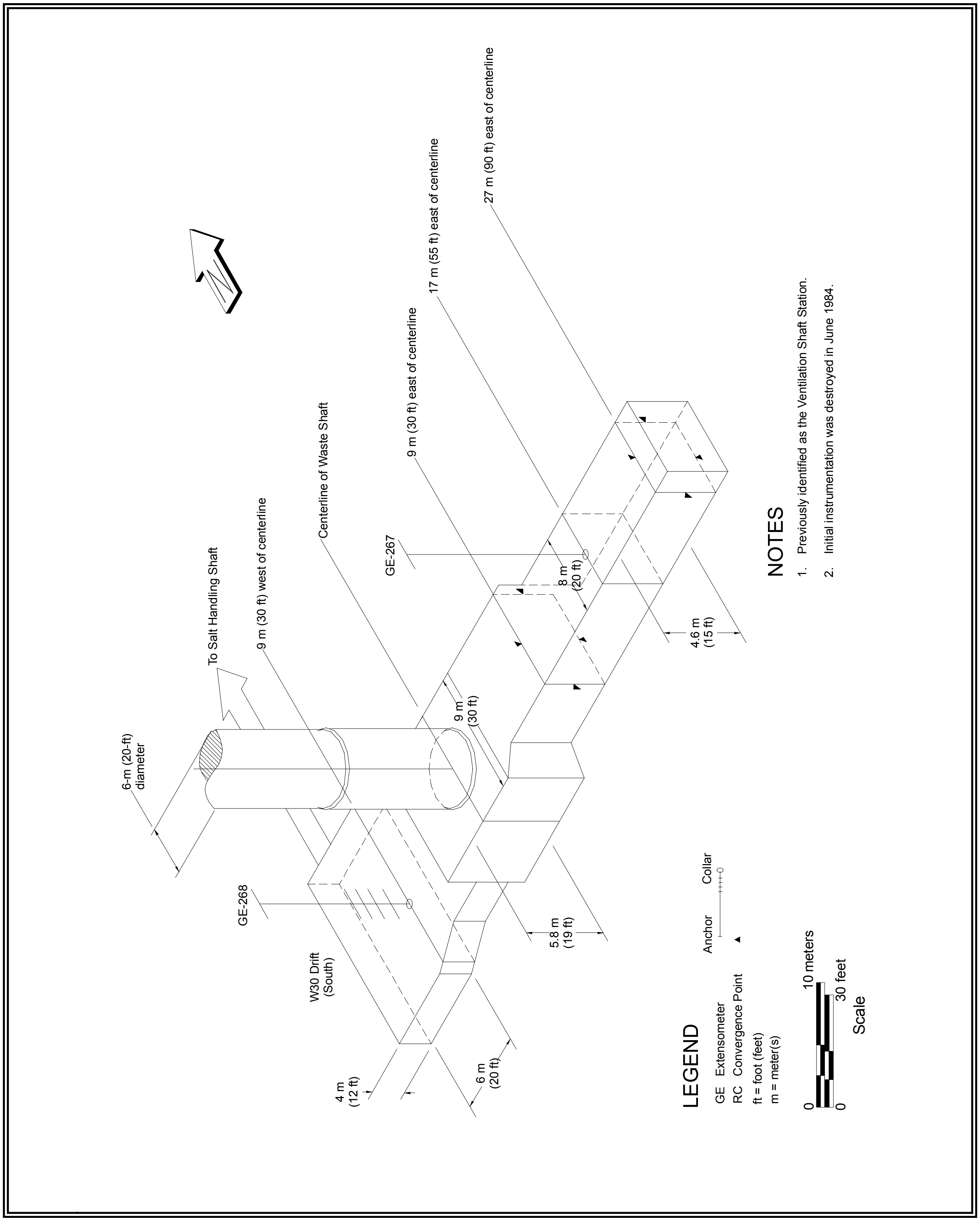


Figure 4-5
Waste Shaft Station Instrumentation Before Wall Trimming

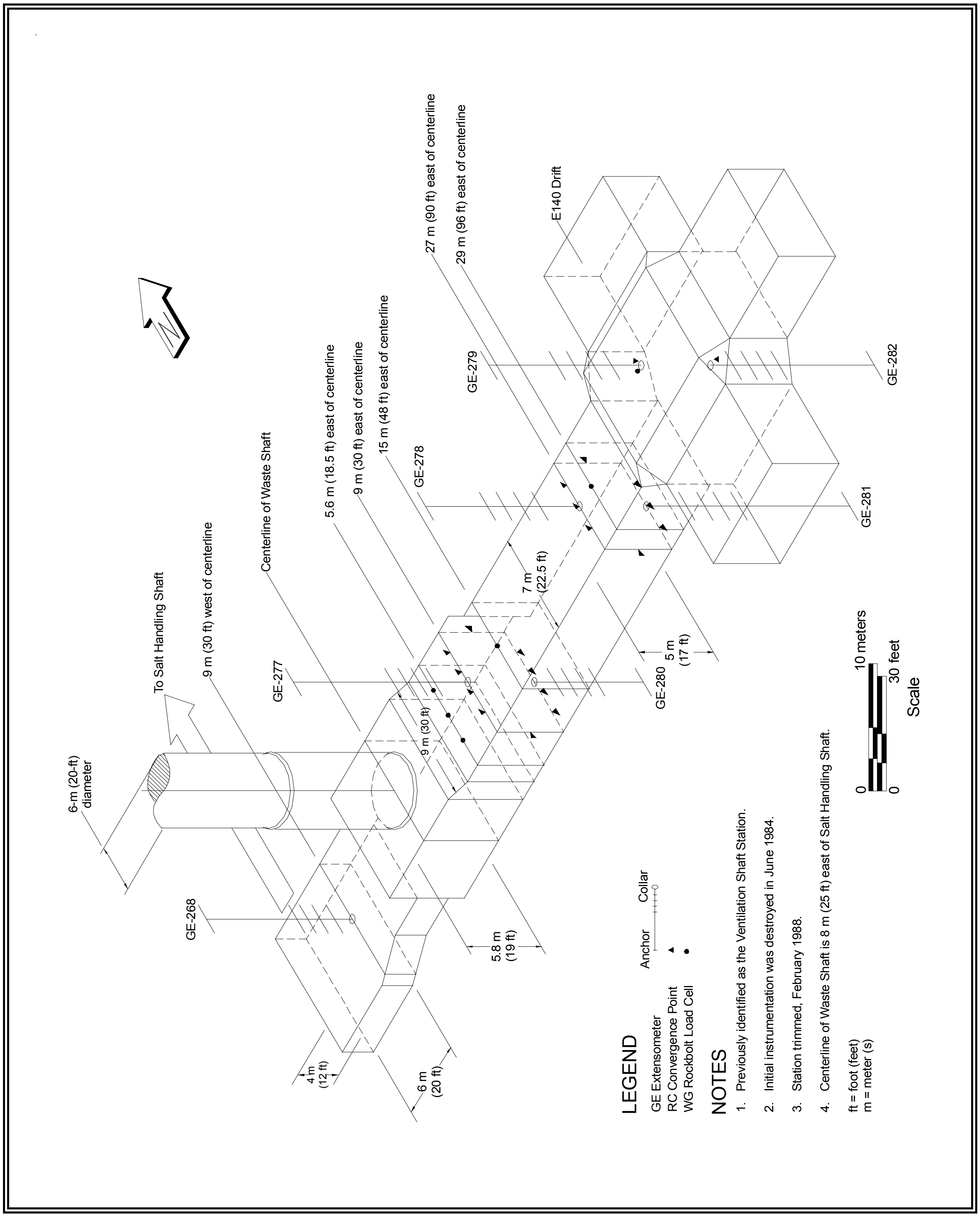


Figure 4-6
Waste Shaft Station Instrumentation After Wall Trimming

Table 4-2
Historical Summary of Roof Extensometers in Waste Shaft Station

Instrument	Location	Date Installed	Last Date Read	Collar Displacement Relative to Deepest Anchor Inches (cm)	Displacement Rate in./yr. (cm/yr.)
51X-GE-00268	S400-W30	10/24/1984	6/11/2001	7.253 (18.423)	0.348 (0.884)
51X-GE-00279	S400-E140	11/29/1988	6/25/2001	8.779 (22.299)	0.715 (1.816)

cm = centimeter(s)
in = inch(es)

Table 4-3
Horizontal Closure Rates in the Waste Shaft Station

Location		1999 to 2000 Closure Rate in./yr. (cm/yr.)	2000 to 2001 Closure Rate in./yr. (cm/yr.)	Percent Rate Change
S400-E30	Rib to Rib	0.951 (2.416)	0.916 (2.327)	-3.7
S400-E90	Rib to Rib	1.061 (2.695)	1.005 (2.553)	-5.3

cm/yr. = centimeter(s) per year.
in./yr = inch(es) per year.

Sixteen rock bolt load cells are installed in the roof and brow of the Waste Shaft Station. The loads on these rock bolts are monitored regularly.

4.3 Air Intake Shaft Station

The Air Intake Shaft Station was excavated in late 1987 and early 1988 using a continuous miner. The Air Intake Shaft is not typically used to transport personnel or materials between the surface and the underground, but does have a work platform that can be raised and lowered in the shaft to perform routine ground control operations. There is minimal operational activity at the Air Intake Shaft Station.

4.3.1 Modifications to Excavation and Ground Control Activities

No modifications or ground control activities, other than routine maintenance, were performed in the Air Intake Shaft Station during this reporting period.

4.3.2 Instrumentation

Convergence point and extensometer instrumentation located near the Air Intake Shaft Station is presented in Chapter 5.0 as part of the discussion on the performance of the access drifts. Twenty rock bolt load cells installed in the Air Intake Shaft Station area are monitored regularly.

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5.0 Performance of Access Drifts

This chapter describes the geomechanical performance of the central underground access drifts. The Northern Experimental Area and the Waste Disposal Area are discussed later in Chapters 6.0 and 7.0, respectively. There are four major north-south drifts in the WIPP underground, intersected by shorter east-west drifts. These drift dimensions range from 8 ft (2.4 m) to 21 ft (6.4 m) in height and from 14 ft (4.3 m) to 33 ft (9.2 m) in width.

5.1 Modifications to Excavation and Ground Control Activities

In preparation for mining Panel 2, the four major north-south access drifts were extended towards the south during this reporting period. Trimming, scaling, and floor milling activities were performed as necessary in many areas throughout the WIPP underground. Table 5-1 summarizes these activities. Table 5-1 also summarizes ground control activities (e.g., rock bolting and installing wire mesh) performed in various locations in the access drifts.

5.2 Instrumentation

Figure 5-1 shows the location of all of the geotechnical instruments within the WIPP access drifts. This section discusses instrumentation details and locations for each instrumentation type.

5.2.1 Borehole Extensometers

There were no new extensometers installed during this reporting period. All operating underground extensometers continue to be monitored. Remotely and manually read extensometers are typically read weekly, although some instruments may be read more frequently. Some extensometers were removed due to mining up to clay G in E140 and E0 drifts.

5.2.2 Convergence Points

Instrumentation installed during this reporting period was limited to the installation and replacement of convergence point arrays and the installation of new monitoring arrays in the newly mined areas. Convergence points were reinstalled in various locations throughout the WIPP underground where rib, back, or floor trimming activities had been performed during this and the previous reporting period. Horizontal and vertical convergence point arrays were installed at various locations in the W170, W30, E140, and

E300 drifts to monitor Panel 2 mining effects. Convergence points within the access drifts are read manually at least every two months, with more frequent monitoring in some areas. Table 5-2 lists the new and replacement convergence points that were installed during this reporting period. Figure 5-1 shows the locations of all of the monitored convergence point arrays in the WIPP access drifts.

Table 5-1
Summary of Modifications and Ground Control Activities in the Access Drifts July 1, 2000, through June 30, 2001

Date Complete	Location	Work Performed
7/2000	Room G Access	Cleared area for muck disposal.
7/2000	S2520 Overcast	Installed Tensar with an assortment of 94 bolts.
7/2000	E300 drift from S90 to S50	Installed supplemental support system.
7/2000	Waste Shaft Station Area	Spot bolted required mechanical bolts.
9/2000	E140 drift between N460 and N1100	Replaced required twelve-foot threaded bar bolts.
11/2000	South Access Drifts.	Initial mining of these access drifts began.
12/2000	Alcoves L1,L2,L3 and L4	Cleared area for muck disposal.
12/2000	W170 drift from S2180 to S2520.	Pattern bolted using ten-foot mechanical bolts.
1/2001	E0 and E140 North	Bolted brows in preparation for roof beam removal.
2/2001	E0 drift from N150 to N300	Removal of roof beam up to Clay G.
5/2001	E0 drift from N300 to N550	Removal of roof beam up to Clay G.
5/2001	N460 Crosscut	Removal of roof beam up to Clay G.
5/2001	E300 drift	Installed bolts and mesh from S2180 to S2520.
5/2001	E0 drift	Installed bolts and mesh from N150 to N460.
6/2001	S90 drift from E0 to E140	Trimmed ribs, back and floor.
6/2001	E140 drift	Installed wire mesh on the back from N300 to N460.
6/2001	E0	Installed wire mesh on the ribs from N150 to N620.

Table 5-2
New and Replaced Convergence Points Installed in the Access Drifts
July 1, 2000 through June 30, 2001

Instrument Type	N/R	Field Tag	*Chord	Location	Date Installed
Convergence Point	N	S2180-E55	A-C	S2180 DRIFT-E55	7/28/00
Convergence Point	N	S2180-E55	B-D	S2180 DRIFT-E55	7/28/00
Convergence Point	R	S2180-W100-2	A-C	S2180 DRIFT-W100	7/28/00
Convergence Point	R	S2180-W100-2	B-D	S2180 DRIFT-W100	7/28/00
Convergence Point	N	S2180-E220	A-C	S2180 DRIFT-E220	8/23/00
Convergence Point	N	S2180-E220	B-D	S2180 DRIFT-E220	8/23/00
Convergence Point	R	E140-S2007-2	A-C	E140 DRIFT-S2007	9/28/00
Convergence Point	R	E140-S2065-2	A-C	E140 DRIFT-S2065	9/28/00
Convergence Point	R	E140-S2122-2	A-C	E140 DRIFT-S2122	9/28/00
Convergence Point	R	E140-S2180-3	A-C	E140 DRIFT-S2180	9/28/00
Convergence Point	R	S1950-E113-4	A-C	S1950 DRIFT-E113	9/28/00
Convergence Point	R	S2180-E55-2	A-C	S2180 DRIFT-E55	10/11/00
Convergence Point	R	W30-S2275-2	A-C	W30 DRIFT-S2275	10/11/00
Convergence Point	R	W30-S2350-2	A-C	W30 DRIFT-S2350	10/11/00
Convergence Point	R	W30-S2425-2	A-C	W30 DRIFT-S2425	10/11/00
Convergence Point	R	W30-S2520-2	A-C	W30-S2520 INTERSECTION	10/11/00
Convergence Point	R	W170-S232-2	A-C	W170 DRIFT-S232	11/15/00
Convergence Point	R	W170-S560-3	A-C	W170 DRIFT-S560	11/15/00
Convergence Point	R	W170-S850-5	B-D	W170 DRIFT-S850	11/16/00
Convergence Point	R	W170-S850-6	H-F	W170 DRIFT-S850	11/16/00
Convergence Point	N	W170-S2685	A-C	W170 DRIFT-S2685	1/10/01
Convergence Point	N	W170-S2685	B-D	W170 DRIFT-S2685	1/10/01
Convergence Point	N	W30-S2685	A-C	W30 DRIFT-S2685	1/10/01
Convergence Point	N	W30-S2685	B-D	W30 DRIFT-S2685	1/10/01
Convergence Point	R	W170-S850-6	A-E	W170 DRIFT-S850	2/5/01
Convergence Point	R	E140-S700-5	A-D	E140-S700 INTERSECTION	3/22/01
Convergence Point	R	W170-S1000-2	A-C	W170 DRIFT-S1000	3/22/01
Convergence Point	R	S1950-E311-5	A-C	S1950 DRIFT-E311	5/14/01

N = New instrument.
R = Replacement instrument (i.e., instrument replaces older instrument that has failed or has been mined out).
*Chord is defined in "Geotechnical Analysis Report for July 2000–June 2001 Supporting Data."

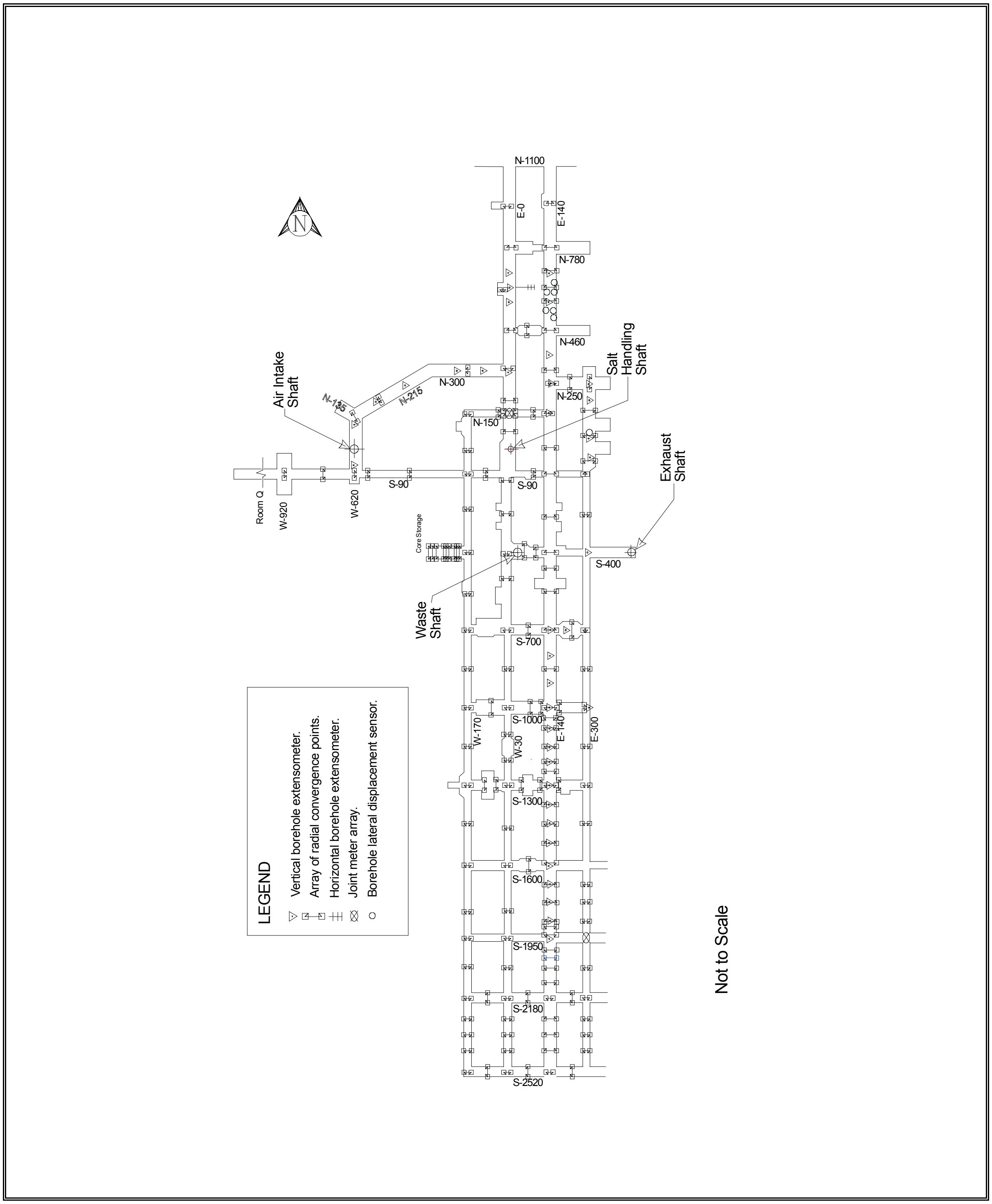

Figure 5-1
Location of Geotechnical Instruments in the Access Drifts

5.3 Analysis of Extensometer and Convergence Point Data

Extensometer data are obtained by measuring the displacement from the reference head anchor (collar) to each fixed anchor of the extensometer. Convergence point data are obtained by measuring the change in distance between fixed points anchored into the rock across an opening, either from rib to rib or from roof to floor. Convergence measurements are a primary means of identifying areas where conditions may be becoming unstable. These measurements are made, at a minimum, every two months throughout the WIPP underground. Extensometer displacement rates and convergence rates indicate how an excavation is performing; rates that decrease or are relatively constant typify stable excavations, whereas increasing rates may indicate some type of developing instability.

Routinely, extensometer displacement rates and convergence rates are plotted against time, and comparisons are made between consecutive rates to identify any acceleration. Annual convergence rates are calculated by determining the difference between the first and last readings of the reporting period and dividing that difference by the time between the two readings (in years). Instruments that indicate acceleration are then analyzed to determine the significance of the acceleration. Factors that are considered during the analysis include the magnitude of the respective rates, percentage increase, convergence history, and any recent excavation in the vicinity.

There are 20 active borehole extensometers being monitored at various locations in the access drifts. The majority of these instruments are located in the E140 drift. Where data are available, annual displacement rates were calculated for each of the active extensometers and compared to the annual displacement rates from the previous reporting period. Significant percentage increases in displacement rates were observed in the E140 drift between S1378 and S1900. Percentage increases in displacement rates in this area range from 10.2% at E140 S1378 to 47.7% at E140 S1775. The increased movement in the roof rates can be attributed to a clay stringer separation approximately 12” to 18” above the back.

Where possible, annual closure rates were calculated from convergence point array data from the access drifts. A complete tabulation of these convergence point data and calculated closure rates are presented in the supporting data document for this report[5]. Locations with increases in annual vertical and horizontal closure rates of greater than 10 percent are listed in Table 5-3.

Further analysis of these accelerations has shown many of them to be relatively insignificant (i.e. significant accelerations cannot be controlled by routine ground control maintenance). Others, such as the southern areas of the access drifts had closure rate increases that can be directly attributed to Panel 2 mining. These rates are expected to decrease with time as the Panel 2 stress effects are redistributed. An analysis using the running median of the convergence rate was used on the locations in Table 5-3 where ground control measures (trimming or rock bolting) were not instituted during this reporting period. The convergence point pairs in E140 between S1450 and S1900, show a trend of increasing convergence rates over the long-term median convergence rate. This is due to a separation caused by a clay stringer approximately 12” to 18” above the back.

5.4 Excavation Performance

Bimonthly assessments of underground excavations continue to indicate that convergence rates vary with seasonal temperature variations; typically increasing during the warmer summer months and decreasing during the cooler winter months. Over 500 readings are collected and assessed from convergence point pairs located throughout the WIPP underground on a regular basis.

The performance of the access drift excavations during this reporting period iswithin acceptable criteria. “Acceptable criteria” is when the drift remains accessible and the ground can be controlled by routine maintenance. Only standard remedial ground control maintenance was required to maintain the performance of the excavations.

[5] Instrumentation data and data plots are available in “Geotechnical Analysis Report for July 2000-June 2001 Supporting Data.” This document is available upon request from Westinghouse TRU Solutions. Refer to Foreword and Acknowledgements for details and address.

Table 5-3
Increases in Annual Vertical Convergence Rates Greater than 10 Percent Access Drifts

Location	*Chord	Last Reading 2000 to 2001 Date	Closure Rate 2000 to 2001 in/year	1999 to 2000 in/year	Rate Change Percent[a]	Comments
E300 Drift-S1775	A-C	06/15/2001	0.665	0.601	10.6%	Influenced by Panel 2 mining.
E300 Drift-S1862	A-C	06/15/2001	0.675	0.610	10.7%	Influenced by Panel 2 mining.
E140 Drift-S1378	H-F	06/12/2001	2.272	2.061	10.2%	Influenced by Panel 2 mining.
E140 Drift-S1456	A-G	06/12/2001	2.479	2.041	21.5%	Influenced by Panel 2 mining.
E140 Drift-S1534	A-E	06/12/2001	4.455	3.219	38.4%	Influenced by Panel 2 mining.
E140 Drift-S1534	B-D	06/12/2001	2.256	1.710	31.9%	Influenced by Panel 2 mining.
E140 Drift-S1534	H-F	06/12/2001	2.812	2.323	21.1%	Influenced by Panel 2 mining.
E140 Drift-S1687	A-E	06/12/2001	2.358	2.043	15.4%	Influenced by Panel 2 mining.
E140 Drift-S1687	B-D	06/12/2001	2.157	1.943	11.0%	Influenced by Panel 2 mining.
E140 Drift-S1775	A-G	06/12/2001	3.584	2.427	47.7%	Influenced by Panel 2 mining.
E140 Drift-S1775	B-F	06/12/2001	3.638	2.692	35.1%	Influenced by Panel 2 mining.
E140 Drift-S1775	L-H	06/12/2001	1.810	1.549	16.8%	Influenced by Panel 2 mining.
E140 Drift-S1862	A-E	06/12/2001	2.259	1.885	19.8%	Influenced by Panel 2 mining.
E140 Drift-S1862	B-D	06/12/2001	2.330	2.069	12.6%	Influenced by Panel 2 mining.
E140 Drift-S1862	H-F	06/12/2001	1.435	1.253	14.5%	Influenced by Panel 2 mining.
E140 Drift-S2007	A-C	06/12/2001	2.609	2.296	13.6%	Influenced by Panel 2 mining.
E140 Drift-S2065	A-C	06/12/2001	2.489	2.011	23.8%	Influenced by Panel 2 mining.
E140 Drift-S2122	A-C	06/12/2001	2.770	2.287	21.1%	Influenced by Panel 2 mining.
S90-W400	A-C	06/18/2001	0.782	0.644	21.4%	
S90-W620	A-C	06/18/2001	1.364	1.213	12.4%	
S1000-E58	A-C	06/12/2001	1.378	1.229	12.1%	

[a] Increase in convergence rate is calculated from the difference between the 1999–2000 rate and the 2000–2001 rate.

*Chord is defined in "Geotechnical Analysis Report for July 2000–June 2001 Supporting Data."

in./year. = inch(es) per year.

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6.0 Performance of Northern Experimental Area

This chapter describes the geomechanical performance of the rooms and access drifts located in the Northern Experimental Area. This area includes all excavations north of the N1100 drift including the SPDV rooms, the N1400 and N1100 drifts, the E0 and E140 drifts between N1100 and N1400, and the E300 shop. Sections of this area have been deactivated. Restricted access to some of this area precludes direct observation of instruments or the installation of new instruments; therefore, only data from remotely read instruments are available in deactivated areas.

6.1 Modifications to Excavation and Ground Control Activities

- Spot bolted, replacing failed bolts
- Start muck disposal/backfilling

6.2 Entry into Deactivated Area

Access to this area was blocked in August and September 1996 by the construction of barriers in the E0 and E140 drifts at N800. In October and November 1999 members of the Geotechnical Engineering Section and Underground Operations made a re-entry into portions of the deactivated Northern Experimental Area.

6.3 Instrumentation

Active, remotely read, geotechnical instrumentation located in the Northern Experimental Area consists of borehole extensometers and wire convergence meters. Figure 6-1 shows the locations of the active and inactive instruments in the Northern Experimental Area. Monitoring of accessible manually read instrumentation was re-established during this re-entry.

6.3.1 Borehole Extensometers

Data were collected remotely from seven extensometers located in the Northern Experimental Area from July to November 2000. Table 6-1 presents the collar displacement relative to the deepest anchor at the end of this reporting period. A comparison of calculated displacement rates between the current and previous reporting periods cannot be made due to removal of the data logger in preparation for beam removal mining in the E140 and E0 drifts.

6.3.2 Wire Convergence Meters

Manual convergence measurements continue in accessible areas. Wire convergence meters continue to be monitored in areas east of the E140 drift.

6.4 Excavation Performance

Based on the extensometer and convergence data, the annual closure rates within many of these monitored rooms and drifts continue to be relatively constant. One exception includes the roof extensometer installation in SPDV Room L4. The roof displacement data indicates that lateral displacement at the clay seam may be influencing the results.

6.5 Analysis of Convergence Data

As described in Section 5.3, convergence measurements are a primary means of identifying areas where conditions may be becoming unstable. Due to the lack of convergence data in this area, no analysis can be performed.

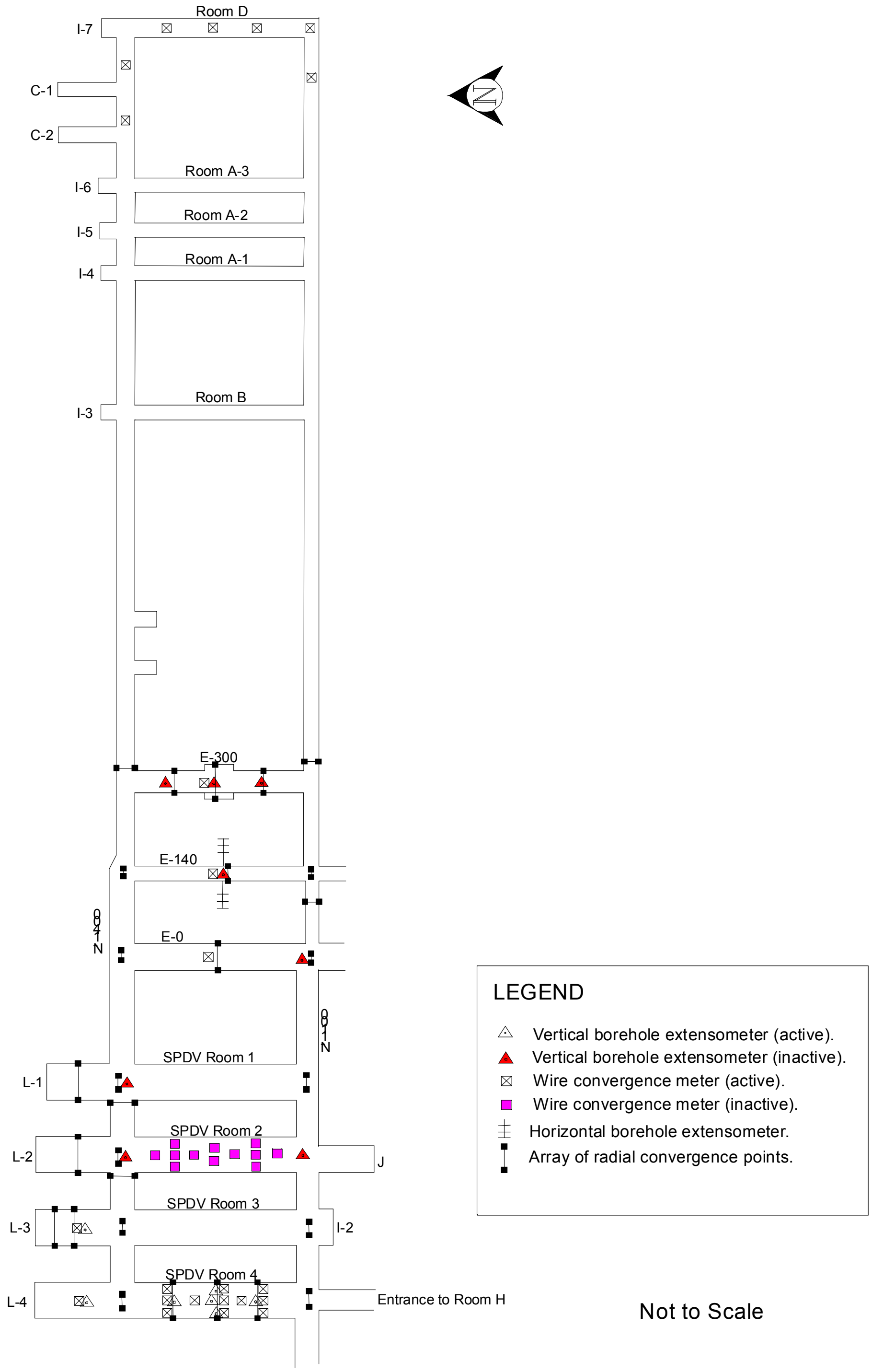

Figure 6-1
Location of Active and Inactive Geotechnical Instruments in the Northern Experimental Area

Table 6-1
Results of Remotely Read Extensometers in the Northern Experimental Area (All Vertical)

Location		Date of Last Reading	Collar Displacement Relative to Deepest Anchor (in.)	Collar Displacement Relative to Deepest Anchor (cm)
Room L3	Roof	11/1/2000	5.354	13.599
Room L4	Roof	11/1/2000	2.176	5.527
SPDV Room 4-N1325	Roof	11/1/2000	4.216	10.709
SPDV Room 4-N1250	East 1/4 Pt	11/1/2000	2.055	5.220
SPDV Room 4-N1250	Roof	11/1/2000	3.280	8.331
SPDV Room 4-N1250	West 1/4 Pt	11/1/2000	5.387	13.683
SPDV Room 4-N1175	Roof	11/1/2000	2.449	6.220

cm = centimeter(s)
in. = inch(es)
SPDV = Site Preliminary Design Validation Program

Table 6-2
Vertical Convergence Readings in the Northern Experimental Area Wire Convergence Meters

Field Tag	Location		Date of Initial Reading	Date of Last Reading	Change from Initial Reading	
					Inches	Centimeter
51X-CW-00033	N1420 Drift - E1551		10/02/1995	11/01/2000	5.160	13.106
51X-CW-00032	N1420 Drift - E1451		10/02/1995	11/01/2000	4.750	12.065
51X-CW-00034	Room D - N1342	Centerline	10/02/1995	11/01/2000	6.614	16.800
51X-CW-00035	Room D - N1266	Centerline	10/02/1995	11/01/2000	6.410	16.281
51X-CW-00036	Room D - N1187	Centerline	10/02/1995	11/01/2000	6.258	15.895
51X-CW-00037	N1100 Drift - E1620		10/02/1995	11/01/2000	3.603	9.152
51X-CW-00038	N1100 Drift - E1530		10/02/1995	11/01/2000	1.181*	3.000
51X-CW-00039	E300 Drift - N1275		10/02/1995	11/01/2000	15.977	40.582

* Instrument bumped during re-entry.

7.0 Performance of Waste Disposal Area

Excavation of the waste disposal area began in May 1986 with the mining of entries to Panel 1. Initially, the disposal rooms and drifts were developed as pilot drifts that were later excavated to 13 ft (4 m) high, 33 ft (10 m) wide, and 300 ft (91 m) long. Room 1 was excavated to these dimensions in August 1986, and pilot drifts for Rooms 2 and 3 were excavated in January and February 1987. Rooms 2 and 3 were excavated to final dimensions in February and March 1988 and Rooms 4 through 7 were completed in May 1988. Short access drifts designed to lead to smaller test alcoves were excavated north off of the S1600 drift in June 1989. Only the access drifts to the alcoves were completed; the alcoves were not excavated.

7.1 Modifications to Excavations and Ground Control Activities

No new excavations were mined in the Panel 1 waste disposal area during the reporting period of July 2000 through June 2001. Routine maintenance and ground control activities in the form of trimming, scaling, rock bolt replacement, and installing wire mesh was performed on ribs, floor, and roof throughout Panel 1. Table 7-1 summarizes the ground control activities performed in Panel 1 and Panel 2 during this reporting period.

Mining of Panel 2 was completed in August 2000. All of the rooms and access drifts were excavated and were trimmed to final dimensions. Some areas of drummy ground were encountered during mining. These areas were easily addressed by trimming to intact rock or installing short mechanical roof bolts.

Table 7-1
Summary of Modifications and Ground Control Activities in the Waste Disposal Area
July 1, 2000 through June 30, 2001

Date Completed	Location	Work Performed
7/2000	Panel 1, Room 1	Replaced 13 supplemental support rock bolts.
7/2000	S1600 between Room 5 and 6	Installed cable slings.
7/2000	Panel 2	Installed over 75 two-foot rock bolts in drummy areas.
7/2000	Panel 1, Room 7	Replacement of 30 twelve-foot rock bolts.
8/2000	Panel 2	Completed mining.
9/2000	Panel 1, Room 7	Floor milling from S1720 to S1965.
9/2000	S1600 between Room 1 and 7	Replaced twelve-foot threaded bar rock bolts.
12/2000	S1600 between Room 1 and 6	Completed cable sling installation.
3/2001	S1950 drift	Floor milling from rooms 2 to 7 complete.
5/2001	S1950 drift from rooms 4 to 6	Installed roof mats.

7.2 Instrumentation

No extensometers were installed or replaced in Panel 1 during this reporting period. Thirteen convergence points were replaced in the S1950 drift entry (between E300 and Room 7) during this reporting period. Table 7-2 lists the convergence points installed or replaced in Panels 1 and 2. Figure 7-1 shows the location of the various types of geotechnical instruments in Panel 1 of the Waste Disposal Area. Figure 7-2 shows the location of the various types of geotechnical instruments in Panel 2 of the Waste Disposal Area.

The 286 rock bolt load cells of the yielding roof support system in Room 1 are monitored regularly. As the roof beam expands the tension in the rock bolts increases. Detensioning of the rock bolts was performed approximately every five weeks to maintain a specified load range during previous reporting periods. However, during this reporting period, the loads were allowed to increase until failure of the rock bolt. The failed rock bolts are replaced with a similar installation. These installations also include a Titan load indicator. The load indicators provide additional yield capacity thus extending the useful life of the bolt.

7.3 Excavation Performance

In order to collect early convergence data, convergence points were installed at selected locations immediately following initial excavation. Horizontal and vertical convergence rates have been calculated at the center of each of the rooms in Panel 1 for this and the previous two reporting periods. Tables 7-3 and 7-4 present these convergence rates. The vertical convergence rates at the center of each of the rooms in Panel 1 have all increased with the exception of Room 2, which decreased during the current reporting period relative to each of the two previous reporting periods. All the horizontal convergence rates at each room center have increased during the current reporting period relative to the previous period.

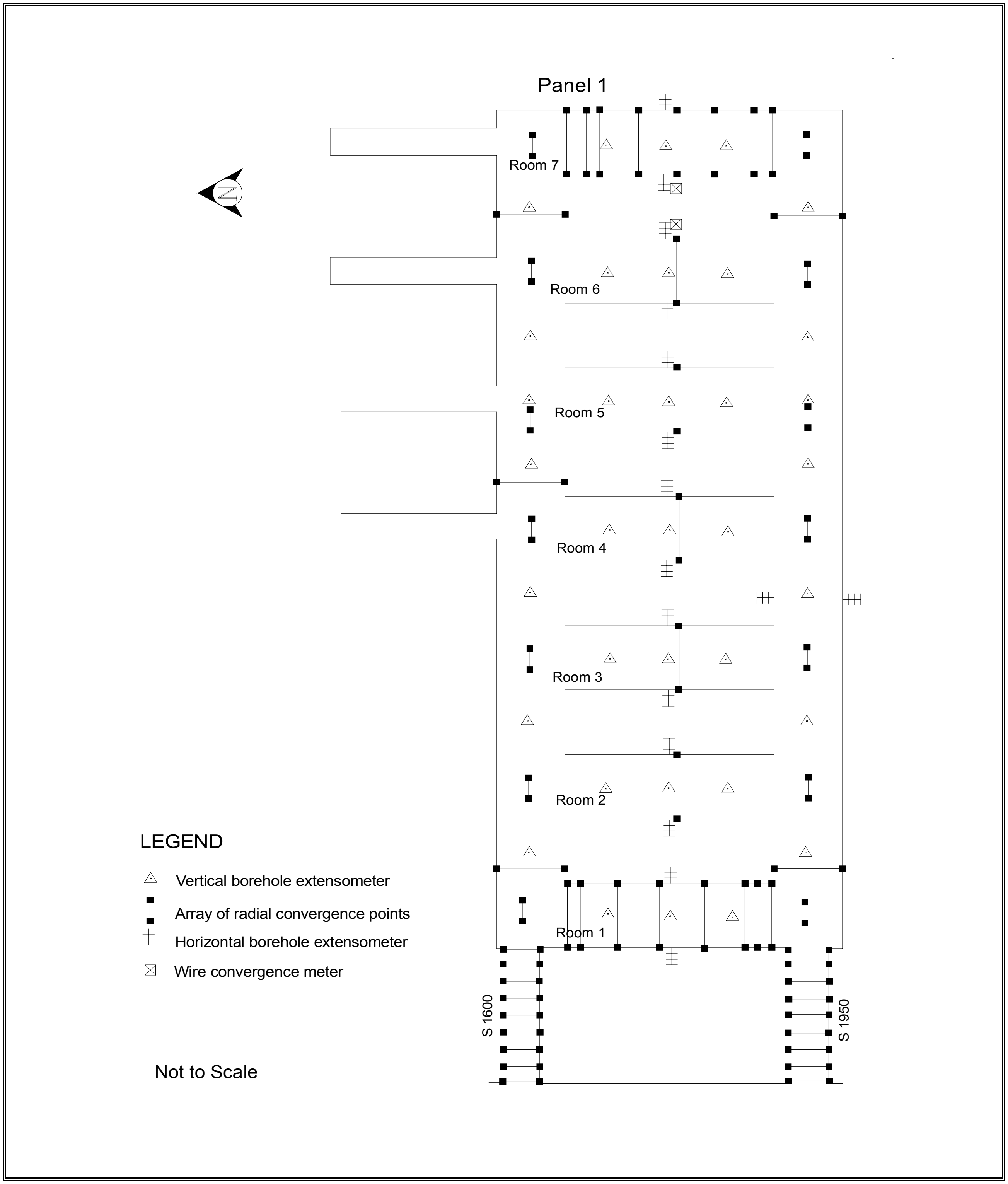

Figure 7-1
Location of Panel 1 Geotechnical Instruments

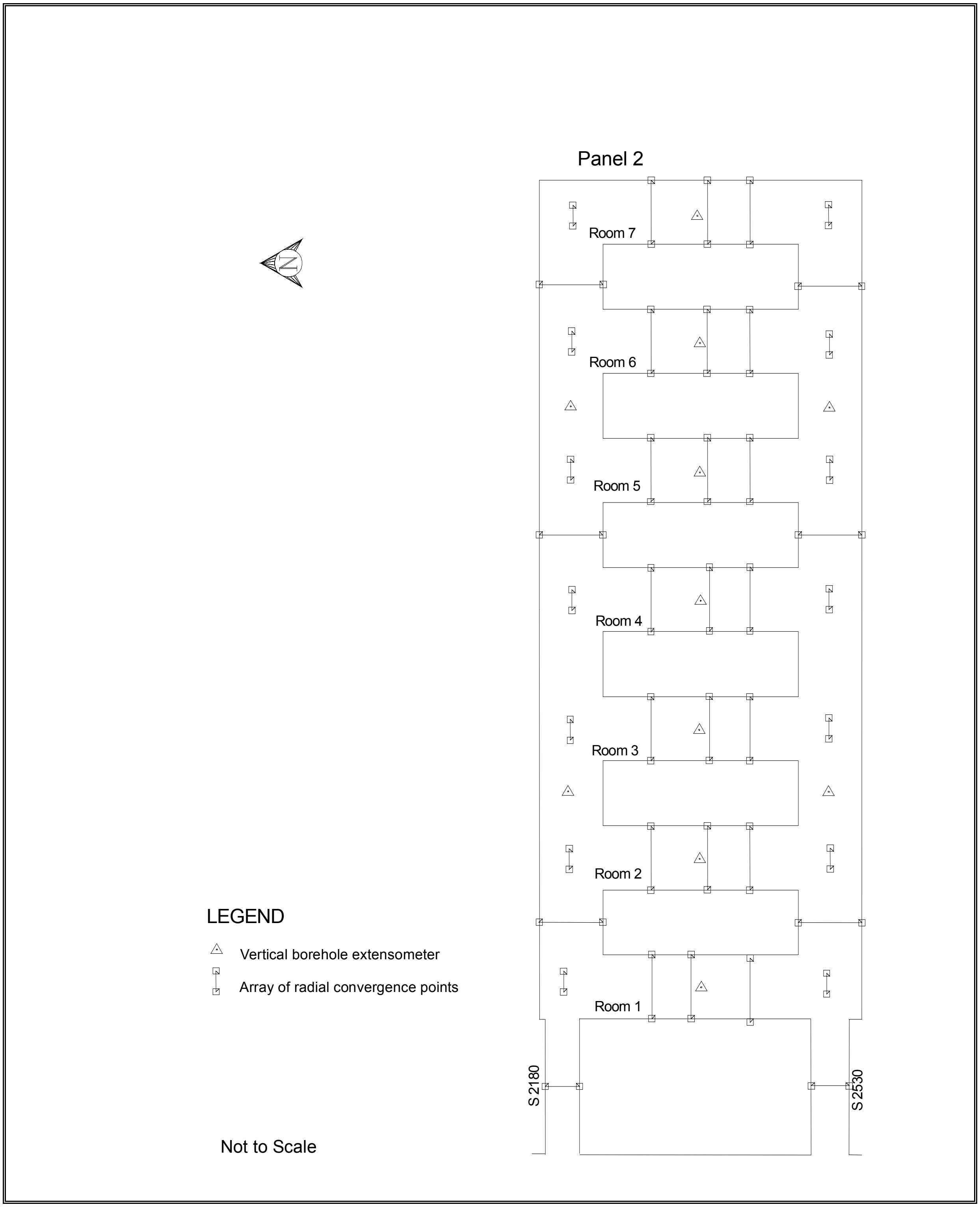

Figure 7-2
Location of Panel 2 Geotechnical Instruments

Table 7-2
New and Replaced Instruments in the Waste Disposal Area
July 1, 2000, through June 30, 2001

Instrument Type	N/R	Field Tag*	Location	Date Installed
Convergence Point	N	E790-S2275 (A-C)	PANEL 2: E790-S2275	7/11/00
Convergence Point	N	E790-S2275 (B-D)	PANEL 2: E790-S2275	7/11/00
Convergence Point	R	E790-S2350-2 (A-C)	PANEL 2: E790-S2350	7/11/00
Convergence Point	N	E790-S2350 (B-D)	PANEL 2: E790-S2350	7/11/00
Convergence Point	N	E790-S2425 (A-C)	PANEL 2: E790-S2425	7/11/00
Convergence Point	N	E790-S2425 (B-D)	PANEL 2: E790-S2425	7/11/00
Convergence Point	N	E790-S2520 (A-C)	PANEL 2: E790-S2520 Intersection	7/11/00
Convergence Point	N	E920-S2275 (A-C)	PANEL 2: E920-S2275	7/12/00
Convergence Point	N	E920-S2275 (B-D)	PANEL 2: E920-S2275	7/12/00
Convergence Point	N	E920-S2350 (B-D)	PANEL 2: E920-S2350	7/12/00
Convergence Point	R	E920-S2350-2 (A-C)	PANEL 2: E920-S2350	7/12/00
Convergence Point	N	E920-S2425 (B-D)	PANEL 2: E920-S2425	7/12/00
Convergence Point	N	E920-S2425 (A-C)	PANEL 2: E920-S2425	7/12/00
Convergence Point	N	E1320-S2180 (A-C)	PANEL 2: E1320-S2180 Intersection	7/20/00
Convergence Point	N	E1320-S2275 (A-C)	PANEL 2: E1320-S2275	7/20/00
Convergence Point	N	E1320-S2275 (B-D)	PANEL 2: E1320-S2275	7/20/00
Convergence Point	N	E1320-S2350 (B-D)	PANEL 2: E1320-S2350	7/20/00
Convergence Point	N	S2520-E1265 (A-C)	PANEL 2: S2520-E1265	7/20/00
Convergence Point	N	S2520-E1265 (B-D)	PANEL 2: S2520-E1265	7/20/00
Convergence Point	N	S2180-E1265 (A-C)	PANEL 2: S2180-E1265	7/20/00
Convergence Point	N	S2180-E1265 (B-D)	PANEL 2: S2180-E1265	7/20/00
Convergence Point	N	E1320-S2425 (A-C)	PANEL 2: E1320-S2425	7/20/00
Convergence Point	N	E1320-S2425 (B-D)	PANEL 2: E1320-S2425	7/20/00
Convergence Point	R	E1320-S2350-2 (A-C)	PANEL 2: E1320-S2350	7/20/00
Convergence Point	N	E1320-S2520 (A-C)	PANEL 2: E1320-S2520	7/20/00
Convergence Point	N	S2520-E1190 (A-C)	PANEL 2: S2520-E1190 Intersection	7/26/00
Convergence Point	N	E1190-S2275 (A-C)	PANEL 2: E1190-S2275	7/26/00
Convergence Point	N	E1190-S2275 (B-D)	PANEL 2: E1190-S2275	7/26/00
Convergence Point	N	E1190-S2425 (A-C)	PANEL 2: E1190-S2425	7/26/00
Convergence Point	N	E1190-S2425 (B-D)	PANEL 2: E1190-S2425	7/26/00
Convergence Point	R	E1190-S2350-2 (A-C)	PANEL 2: E1190-S2350	7/26/00
Convergence Point	N	E1190-S2350 (B-D)	PANEL 2: E1190-S2350	7/26/00
Convergence Point	N	S2520-E920 (A-C)	PANEL 2: S2520-E920 Intersection	7/27/00
Convergence Point	N	S2520-E985 (A-C)	PANEL 2: S2520-E985	7/27/00
Convergence Point	N	S2520-E985 (B-D)	PANEL 2: S2520-E985	7/27/00
Convergence Point	N	S2520-E1050 (A-C)	PANEL 2: S2520-E1050 Intersection	7/27/00
Convergence Point	N	E1050-S2275 (A-C)	PANEL 2: E1050-S2275	7/27/00
Convergence Point	N	E1050-S2275 (B-D)	PANEL 2: E1050-S2275	7/27/00
Convergence Point	R	E1050-S2350-2 (A-C)	PANEL 2: E1050-S2350	7/27/00
Convergence Point	N	E1050-S2350 (B-D)	PANEL 2: E1050-S2350	7/27/00
Convergence Point	N	E1050-S2425 (A-C)	PANEL 2: E1050-S2425	7/27/00
Convergence Point	N	E1050-S2425 (B-D)	PANEL 2: E1050-S2425	7/27/00

*Field tag chords is defined in "Geotechnical Analysis Report for July 2000–June 2001 Supporting Data.

Table 7-2 Continued

Instrument Type	N/R	Field Tag*	Location	Date Installed
Convergence Point	N	S2180-E410 (A-C)	PANEL 2: S2180-E410	8/24/00
Convergence Point	N	S2180-E410 (B-D)	PANEL 2: S2180-E410	8/24/00
Convergence Point	N	S2180-E520 (A-C)	PANEL 2: S2180-E520 Intersection	8/24/00
Convergence Point	N	S2180-E660 (A-C)	PANEL 2: S2180-E660 Intersection	8/24/00
Convergence Point	N	S2180-E790 (A-C)	PANEL 2: S2180-E790 Intersection	8/24/00
Convergence Point	N	S2180-E920 (A-C)	PANEL 2: S2180-E920 Intersection	8/24/00
Convergence Point	N	S2180-E986 (A-C)	PANEL 2: S2180-E986	8/24/00
Convergence Point	N	S2180-E986 (B-D)	PANEL 2: S2180-E986	8/24/00
Convergence Point	N	S2180-E1050 (A-C)	PANEL 2: S2180-E1050 Intersection	8/24/00
Convergence Point	N	S2180-E1190 (A-C)	PANEL 2: S2180-E1190 Intersection	8/24/00
Convergence Point	N	S2180-E586 (A-C)	PANEL 2: S2180-E586	8/24/00
Convergence Point	N	S2180-E586 (B-D)	PANEL 2: S2180-E586	8/24/00
Convergence Point	R	S2520-E520-2 (A-C)	PANEL 2: S2520-E520 Intersection	8/25/00
Convergence Point	R	S2180-E1050-2 (A-C)	PANEL 2: S2180-E1050 Intersection	9/28/00
Convergence Point	R	S2180-E1265-2 (A-C)	PANEL 2: S2180-E1265	9/28/00
Convergence Point	R	E1320-S2180-2 (A-C)	PANEL 2: E1320-S2180 Intersection	9/28/00
Convergence Point	R	E1320-S2275-2 (A-C)	PANEL 2: E1320-S2275	9/28/00
Convergence Point	R	E1320-S2350-3 (A-C)	PANEL 2: E1320-S2350	9/28/00
Convergence Point	R	E1320-S2425-2 (A-C)	PANEL 2: E1320-S2425	9/28/00
Convergence Point	R	S2520-E1265-2 (A-C)	PANEL 2: S2520-E1265	9/28/00
Convergence Point	R	S2520-E1190-2 (A-C)	PANEL 2: S2520-E1190 Intersection	9/28/00
Convergence Point	R	E1190-S2425-2 (A-C)	PANEL 2: E1190-S2425	9/28/00
Convergence Point	R	E1190-S2350-3 (A-C)	PANEL 2: E1190-S2350	9/28/00
Convergence Point	R	E1190-S2275-2 (A-C)	PANEL 2: E1190-S2275	9/28/00
Convergence Point	R	S2520-E410-2 (A-C)	PANEL 2: S2520-E410	9/28/00
Convergence Point	R	S1950-E1320-5 (A-C)	PANEL 1: S1950-E1320	11/27/00
Convergence Point	R	S1950-E332-4 (B-D)	PANEL 1: S1950-E332	12/05/00
Convergence Point	R	S1950-E357-4 (B-D)	PANEL 1: S1950-E357	12/05/00
Convergence Point	R	E520-S1853-2 (B-D)	PANEL 1: E520-S1853	12/05/00
Convergence Point	R	E520-S1884-4 (C-G)	PANEL 1: E520-S1884	12/05/00
Convergence Point	R	E1320-S1887-2 (A-C)	PANEL 1: E1320-S1887	12/05/00
Convergence Point	R	E1320-S1850-2 (A-E)	PANEL 1: E1320-S1850	12/05/00
Convergence Point	R	E1320-S1850-2 (B-D)	PANEL 1: E1320-S1850	12/05/00
Convergence Point	R	E1320-S1850-2 (H-F)	PANEL 1: E1320-S1850	12/05/00
Convergence Point	R	E1320-S1812-2 (A-C)	PANEL 1: E1320-S1812	12/05/00
Convergence Point	R	E520-S1681-3 (A-E)	PANEL 1: E520-S1681	1/10/01
Convergence Point	R	S1950-E1250-2 (A-E)	PANEL 1: S1950-E1250	2/28/01
Convergence Point	R	S1950-E1250-2 (B-D)	PANEL 1: S1950-E1250	2/28/01
Convergence Point	R	S1950-E1250-2 (H-F)	PANEL 1: S1950-E1250	2/28/01
Convergence Point	R	S1950-E1190-4 (A-C)	PANEL 1: S1950-E1190	2/28/01
Convergence Point	R	S1950-E1050-4 (A-C)	PANEL 1: S1950-E1050	2/28/01
Convergence Point	R	S1950-E986-5 (A-C)	PANEL 1: S1950-E986	2/28/01
Convergence Point	R	E660-S2425-2 (A-C)	PANEL 1: E660-S2425	3/21/01
Convergence Point	R	E660-S2350-3 (A-C)	PANEL 1: E660-S2350	3/22/01
Convergence Point	R	S1950-E586-7 (A-C)	PANEL 1: S1950-E586	5/14/01
Convergence Point	R	S1950-E660-4 (A-C)	PANEL 1: S1950-E660 Intersection	5/14/01
Convergence Point	R	S1950-E790-4 (A-C)	PANEL 1: S1950-E790 Intersection	5/14/01
Convergence Point	R	S1950-E920-6 (A-C)	PANEL 1: S1950-E920 Intersection	5/14/01

*Field tag chords is defined in "Geotechnical Analysis Report for July 2000–June 2001 Supporting Data."

Fracturing within the immediate roof beam contributes to high convergence rates seen in some areas of Panel 1, especially portions of Room 1. The ground support systems in Rooms 1 and 2, Panel 1 are designed specifically to yield in response to deformation and, therefore, have no significant effect on the rate of roof displacement. However, if the roof fracturing increases to the point at which a large section of the rock is detached, the yielding support systems are designed to support the weight of the roof beam (Westinghouse WID, 1999). If conditions in Panel 1 adversely change, the ground support system will be upgraded or adjusted as necessary, or the room will be abandoned.

Table 7-3
Annual Vertical Convergence Rates at the Center of Panel 1 Disposal Rooms

Location		Fieldtag	1998-1999 Convergence Rate in./yr. (cm/yr.)	1999-2000 Convergence Rate in./yr. (cm/yr.)	2000-2001 Convergence Rate in./yr. (cm/yr.)
Room 1	Centerline	E520-S1802-6 A-E	2.44 (6.20)	2.53 (6.43)	2.73 (6.93)
Room 2	Centerline	E660-S1775-5 A-C	2.30 (5.84)	2.47 (6.27)	2.39 (6.07)
Room 3	Centerline	E790-S1775-3 A-C	2.20 (5.60)	2.31 (5.87)	2.67 (6.78)
Room 4	Centerline	E920-S1775-5 A-F	2.08 (5.29)	2.31 (5.87)	2.68 (6.81)
Room 5	Centerline	E1050-S1775-4 A-F	2.12 (5.38)	2.15 (5.46)	2.69 (6.83)
Room 6	Centerline	E1190-S1775-4 A-F	2.07 (5.27)	2.21 (5.61)	2.65 (6.73)
Room 7	Centerline	E1320-S1775 A-E	2.43 (6.18)	2.41 (6.12)	NA[A]

[A] Room closed – unable to obtain readings.
cm/yr = centimeter(s) per year
in./yr = inch(es) per year

Table 7-4
Annual Horizontal Convergence Rates at the Center of Panel 1 Disposal Rooms

Location		Fieldtag	1998-1999 Convergence Rate in./yr. (cm/yr.)	1999-2000 Convergence Rate in./yr. (cm/yr.)	2000-2001 Convergence Rate in./yr. (cm/yr.)
Room 1	Rib center	E520-S1802-3 C-G	1.24 (3.14)	1.33 (3.38)	1.51 (3.84)
Room 2	Rib center	E660-S1775-5 B-D	1.26 (3.19)	1.49 (3.78)	1.61 (4.09)
Room 3	Rib center	E790-S1775-5 B-D	1.58 (4.01)	1.71 (4.34)	1.96 (4.98)
Room 4	Rib center	E920-S1775-5 C-H	1.44 (3.66)	1.59 (4.04)	1.84 (4.67)
Room 5	Rib center	E1050-S1775-5 C-H	1.47 (3.73)	1.51 (3.84)	1.87 (4.75)
Room 6	Rib center	E1190-S1775-4 C-H	1.20 (3.06)	1.26 (3.20)	1.41 (3.58)
Room 7	Rib center	E1320-S1775 C-G	1.21 (3.08)	1.26 (3.20)	NA[A]

[A] Room closed – unable to obtain readings.
cm/yr = centimeter(s) per year
in./yr = inch(es) per year

7.4 Analysis of Extensometer and Convergence Point Data

As discussed in Section 5.3, extensometer data are obtained by measuring the displacement from the reference anchor (collar) to each fixed anchor of the extensometer. Convergence point data are obtained by measuring the change in distance between fixed points anchored into the rock across an opening, either from rib to rib or from roof to floor. Extensometer displacement rates and convergence rates are plotted against time, and comparisons are made between consecutive rates to identify any acceleration. Points that indicate acceleration are then analyzed to determine the significance of the acceleration. Factors that are considered during the analysis include the magnitude of the respective rates, percentage increase, convergence history, and any recent excavation in the vicinity.

There are 35 active extensometers installed in the roofs and ribs of Panel 1 of the Waste Disposal Area with most being located in the disposal rooms. The majority of the extensometers show an increase in the displacement rate. The extensometers with the greatest rate increases are generally located in the southern half of the panel closest to Panel 2. The instrument data indicate a definite response to the mining of Panel 2.

Vertical convergence rates within Panel 1 increased during this reporting period in the disposal rooms and in S1950 Access Drift. The areas with the highest convergence rate increases were generally located closest to Panel 2. These increases confirm the effect of the stress changes associated with mining the new panel. The greatest convergence rate increase (20%) within the disposal rooms themselves is located in Room 5. All of these areas will continue to be monitored closely.

The high closure rates in Panel 2 are generally associated with the initial response of the rock to mining. The convergence rates are higher immediately after mining and then taper off to a lower steady state rate.

8.0 Geoscience Program

The Geoscience Program confirms the suitability of the site through the collection of geologic data from the underground facility, including documentation of the stratigraphy and excavation characteristics. Geologic data is gathered through the mapping of excavation surfaces and the logging of new boreholes. Excavation characteristics are determined from fracture mapping and the logging of fractures and offsets (lateral displacements) in open boreholes. Data collected through these activities support the design and evaluation of ground support systems (Westinghouse WID, 1999).

During this reporting period, the following activities were performed:

- Borehole Inspections
- New Borehole Logging
- Core Logging
- Fracture Mapping
- Stratigraphic Mapping

8.1 Borehole Inspections

Geotechnical observation boreholes are drilled at various locations throughout the underground facility. A location may contain one or several boreholes arranged in an array. These holes are drilled to depths that allow the monitoring of fracture development and offsetting and are inspected for the development of those features.

Roof observation holes usually intersect clays G and H (Figure 8-1). Floor observation holes are no longer monitored due to infilling of the holes with crushed salt. There are no separation or offset data for floor observation holes for this reporting period.

The clay seams nearest the excavation surfaces define the immediate roof beam. Clay G defines the roof beam in most of the access drifts and disposal areas. Some areas, such as the Salt Handling Shaft Station and portions of the E140 drift are excavated to clay G and so have roof beams bounded by clay H.

The offset in a borehole is determined by visually estimating the degree of borehole occlusion. The direction of offset along clay seams is observed as the movement of the strata nearer to the observer relative to the strata farther away. Typically the nearer strata

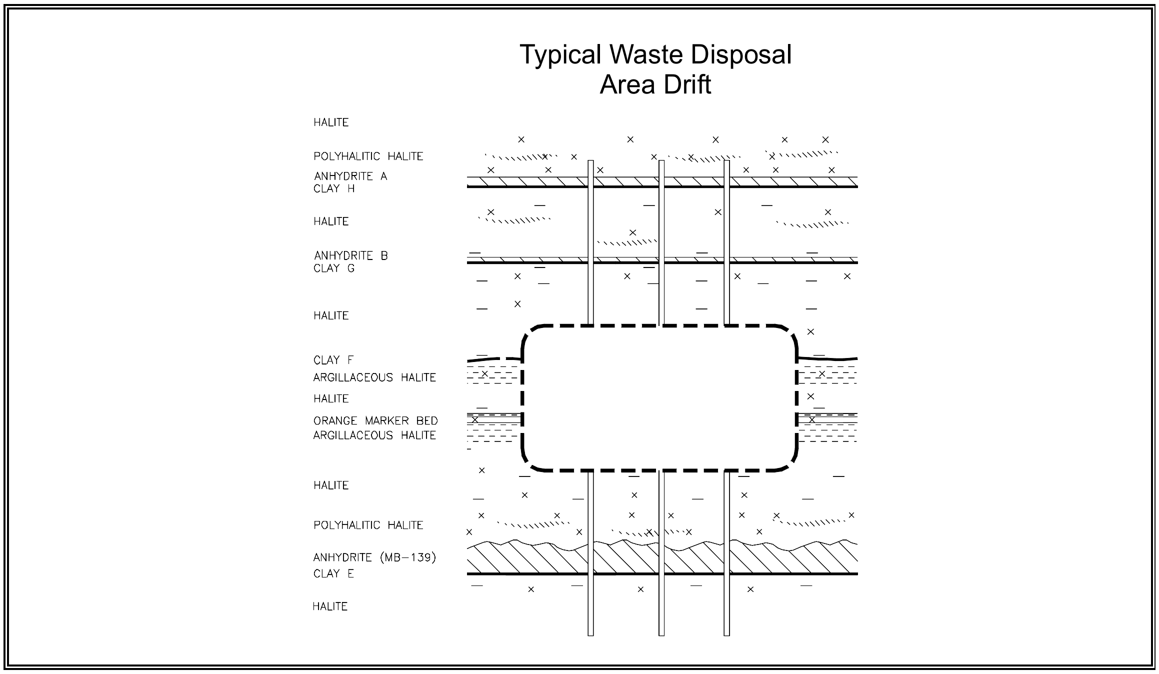

Figure 8-1
Examples of Observation Borehole Layouts

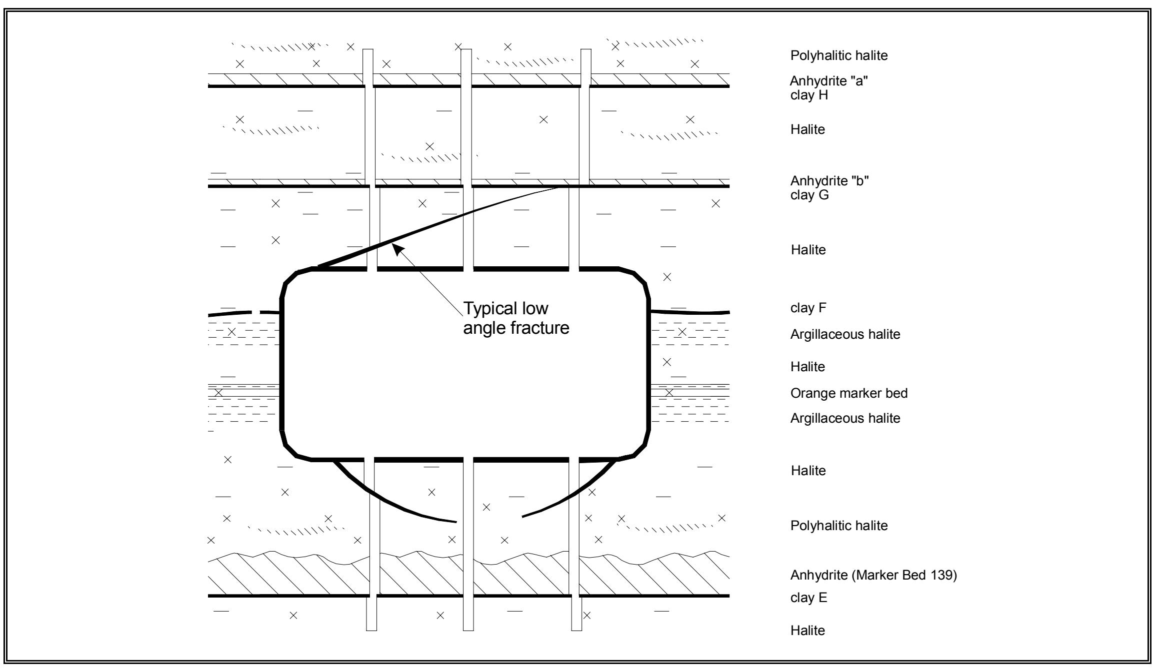

Figure 8-2
Generalized Fracture Pattern

moves toward the center of the excavation (Figure 8-2). Based on previous observations in the underground, the magnitude of offset is usually greater in boreholes located near ribs than in those located along excavation centerlines. Offsetting along the clay layers is observable until the total borehole offset is reached or visibility is obstructed by intervening offsets at other clay seams or fractures. Boreholes are inspected for fractures using an aluminum rod with a flattened steel wire probe attached to one end perpendicular to the rod (referred to as a "scratcher rod"). Fractures and clay seams are located by moving the probe along the sides of the borehole until it is snagged in one of these features. Depth to each feature is recorded, as is the magnitude of separations encountered.

The separation and offset data observed at clay G and clay H in accessible boreholes during this reporting period are presented in Table 7-1 of the supporting data document for this report.[6]

8.2 New Borehole Logging

Newly drilled boreholes are logged either through core logging or remote observation (scratcher rod inspections) to determine the geology in selected areas or to document the location of geologic features for the placement of instruments. Thirty-two new boreholes were drilled and logged during this reporting period. Table 7-2 of the supporting data document presents a summary of new borehole logging activity performed during this reporting period.

8.3 Core Logging

Three holes were drilled in Panel 2 to obtain core samples above and below the excavation horizon. The Supporting Data Document contains the logs for the observation holes, 387, 388 and 388B.

8.4 Fracture Mapping

The Geotechnical Engineering Department routinely maps the progression of fractures in the back exposed on the excavation surfaces of the drifts and rooms in the underground repository. The fracture surveys are generally performed on an annual basis, and the fracture maps are recorded on Mylar sheets or updated as AutoCAD files. The fracture maps facilitate the analysis of strain in the immediate roof-beam as they document the

[6] Instrumentation data and data plots are available in "Geotechnical Analysis Report for July 2000-June 2001 Supporting Data." This document is available upon request from Westinghouse TRU Solutions. Refer to Foreword and Acknowledgments for details and address.

propagation of fractures through time. Figures 7-1 through 7-28 of the supporting data document contain the fracture maps for Panels 1 and 2.

8.5 Stratigraphic Mapping

Stratigraphic mapping was performed after the completion of mining in Panel 2. The east ribs in Rooms 1 through 7 as well as the north rib in South 2180 and the south rib in South 2520 were mapped and prepared as AutoCAD files. The mapping confirms the overall continuity of the relatively horizontal mapping units in the underground. Figures 7-29 through 7-64 of the Supporting Data Document contain the stratigraphic maps for Panel 2.

9.0 Exhaust Shaft Hydraulic Assessment Program

This chapter describes the geotechnical activities associated with monitoring the near surface hydrology at the Exhaust Shaft.

9.1 Hydrologic Monitoring Background

In May 1995, a scheduled inspection revealed a thin stream of water emerging from cracks in the Exhaust Shaft liner located at a depth of approximately 80 ft (24.4 m) below the shaft collar. A catch basin was installed at the base of the Exhaust Shaft in March 1996 to collect excess fluid draining down the shaft walls. In 1997, there were 17,600 gallons of fluid removed from the catch basin followed by 14,335 gallons in 1998, 5,555 gallons in 1999, 4,675 gallons in 2000, and 2,255 gallons through June 2001. As noted above, the fluid emanates from cracks in the shaft's liner. The quantity of fluid reporting to the catch basin appears to be a function of the mode of ventilation, the volume of ventilation airflow, and the temperature and humidity of the ventilation air (DOE, 2000a). At the time of this report, there are two principal seepage horizons in the Exhaust Shaft. The first horizon is located at about 50 ft below the shaft collar. The second horizon is located at about 80 ft (24.4 m) below the shaft collar (Figure 9-1). Since there is no access to the Exhaust Shaft, it is not possible to measure the exact quantity of fluid entering the shaft. Based on examination of quarterly Exhaust Shaft inspection videos, flow into the shaft is estimated at about 1-3 gpm.

Beginning in 1996, the Exhaust Shaft Hydraulic Assessment Program was initiated to investigate the source and extent of the water seeping into the Exhaust Shaft for the purpose of determining mitigation options. Investigations observed a shallow perched groundwater horizon under water-table conditions found in a saturated layer within the lower Santa Rosa Formation and upper few feet of the Dewey Lake Formation (Figure 9-2). The top of the Santa Rosa Formation varies from 28-to-40 ft (8.5 to 12.2 m) bgs, while the base of the Santa Rosa Formation varies from 45-to-75 ft (13.7 to 22.9 m) bgs. The average thickness of the Santa Rosa Formation is about 24 ft (7.3 m) (Table 9-1). Details of these investigations are presented in DOE (1997a, 1997b, and 2000b) and Westinghouse (1997).

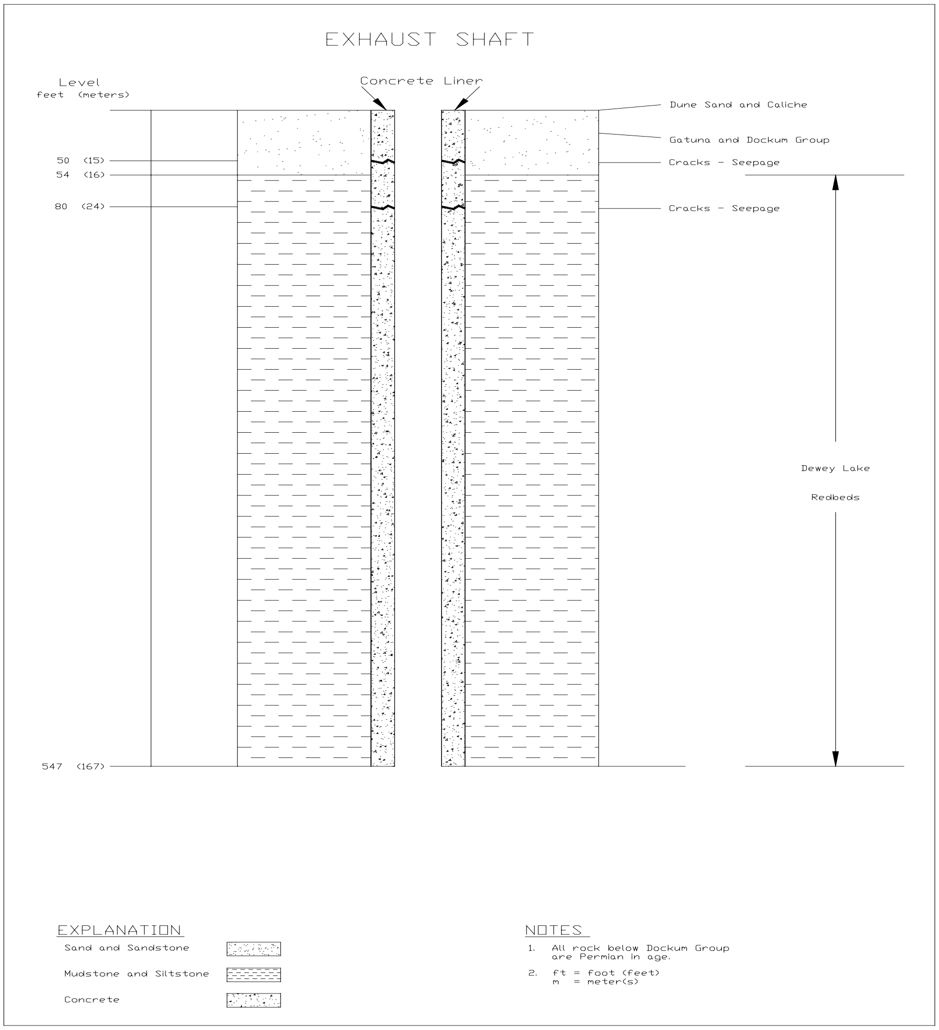

Figure 9-1
Location of Seepage Cracks in Shaft Liner

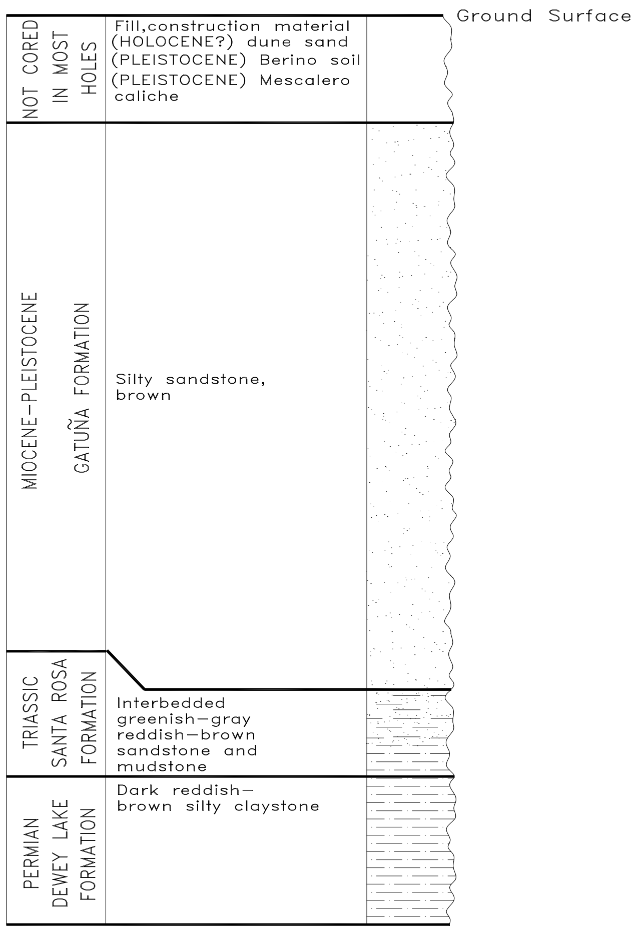

Figure 9-2
Units Commonly Encountered During Shallow Drilling at WIPP

Table 9-1
Depth Interval of Stratigraphic Units

Drill hole	Fill, Dune Sand	Mescalero Caliche	Gatuña Formation	Santa Rosa Formation	Dewey Lake Formation
C-2505	ND*	ND-12.4	12.4-39.6	39.6-54	54-97 (TD)**
C-2506	ND	ND	ND	ND-53.5	53.5-69 (TD)
C-2507	ND	ND	ND	ND-48	48-73 (TD)
C-2811	0-5	5-10	10-35	35-45	45-80 (TD)
Ex Shaft	0-7.5	7.5-17	17-34	34-54	54-546
PZ-1	ND	ND	ND-40	40- ~56	~56-67.5 (TD)
PZ-2	0-9	9-12	12-39	39- ~57	57-65 (TD)
PZ-3	0-8	8-10	10-38	38-63	63-71.1 (TD)
PZ-4	0-9	9-12	12-31	31-57	57-65 (TD)
PZ-5	0-7	7-9	9-36	36-62.5	62.5-71.8 (TD)
PZ-6	0-7	7-9	9-32	32-55	55-66 (TD)
PZ-7	0-7.5	7.5-9.5	9.5-30	30-69	69-72 (TD)
PZ-8	0-6.5	6.5-9	9-31	31-60	60-67.7 (TD)
PZ-9	0-8	8-11	11-36	36-75	75-82 (TD)
PZ-10	0-6	6-9	9-28	28-46	46-57 (TD)
PZ-11	0-10	10-12.5	12.5-34	34-71	71-82 (TD)
PZ-12	0-6	6-8	8-39	39-62	62-77 (TD)

*ND = not determined. Depths are approximate (about ± 1 ft). Some contacts to nearest 0.5 ft due to marked contrast. Where the Gatuña-Santa Rosa contact is difficult to identify; the Gatuña is incorporated with Santa Rosa.
**TD = Total Depth

Investigations resulted in the installation of a network of fifteen monitoring wells and piezometers to determine the areal extent of, and to monitor the water-table elevation and the water quality of the shallow groundwater. Figure 9-3 is a map of the WIPP site monitoring well network for the Exhaust Shaft Hydraulic Assessment Program. Monitoring was performed to assess affects of temporal changes on the flow into the shaft and to support decisions regarding mitigation of the inflow.

Figure 9-3 also shows the location of the monitoring network at WIPP consisting of three wells, C-2505, C-2506, C-2507 and twelve piezometers, PZ-1 through PZ-12, that penetrate the Santa Rosa Formation into the top of the Dewey Lake Formation. Figure 9-4 shows the locations of wells C-2737 and C-2811. Figures 9-5 and 9-6 are diagrams of the typical well and piezometer completions in the Santa Rosa and Dewey Lake Formations. Table 9-1 provides the depth intervals for the respective stratigraphic units in each well or piezometer. Final well and piezometer completion diagrams can be found in the supporting data document.

In February 2001, Westinghouse drilled well C-2737 replacing monitoring well H-1 which monitors the Culebra and Magenta Dolomite Members of the Rustler Formation. During drilling, water was intercepted at a depth of about 62 feet bgs, approximately 17 ft into the Dewey Lake Formation. In response to the presence of water at that horizon, on March 12, 2001, Piezometer C-2811 was drilled. C-2811 is located approximately 110 ft west of C-2737 and 2,500 ft (762.0 m) south of the Exhaust Shaft. C-2811 was completed to a depth of 80.5 ft (24.5 m) bgs (Figure 9-4). The final piezometer completion diagram for C-2811 is presented in Figure 9-7. Results of sampling and analysis of these wells were not available during the reporting period.

9.2 Shaft Observations

Quarterly remote video inspections of the shaft indicate that the shaft is in satisfactory condition. There have been no modifications to the monitoring program during this reporting period.

9.3 Water-Level Monitoring

Water-level measurements have been collected monthly since the completion of the original fifteen wells and piezometers. Water-level measurements began in October 1996 with the completion of wells C-2505, C-2506 and C-2507. The twelve piezometers were completed between June 23 and July 10, 1997. Between October 1996 and December 1997 the fluid levels in the wells and piezometers increased 1-to-4 feet (0.3 to 1.2 m), then stabilized or decreased slightly by as much as 1-to-2 feet (0.3 to 0.6 m) as of June 2001 (Figure 9-8). Figures 9-9 and 9-10 are contour maps comparing water-level elevations from wells and piezometers collected in June 2000 and June 2001. Note that there is little change in the contour plots between June 2000 and June 2001. Except for PZ-12 where there was a 1-foot increase, the other locations changed by less than 0.6 ft (0.2 m). Six wells showed decreases, eight wells showed increases, and one well PZ-8 was dry (Supporting data document). Table 9-2 shows the values used for constructing the water-level contour maps. In addition, the table shows the net change in the fluid level for each respective well and piezometer for the 12-month period. Note that though PZ-8 was dry, an estimated value of 3,350.59 ft (1,021.3 m) above mean seal level (amsl) was used to generate the plot and provide an estimate of the flow field.

Figure 9-11 is a contour map of water-level elevation as of June 2001 but includes a head value from C-2811 taken in April 2001. The contour map indicates a relative high northwest of the WIPP site surface facility near PZ-7. The direction of flow appears to be radially outward from PZ-7 moving to the east in the northern portion of the site and south and southeast in the southern portion of the site. At the same time, PZ-8 is dry suggesting that there may be either a saturation front west of PZ-8 or there may be fluid present at greater depths depending on the fracturing and cementation characteristics of the Dewey Lake.

During FY 2002, responsibility for this shallow groundwater monitoring program was transferred to a newly formed Groundwater Monitoring Section in order to integrate the shallow groundwater results with other WIPP site hydrology programs. In the future, results will be reported in the Annual Site Environmental Report (ASER).

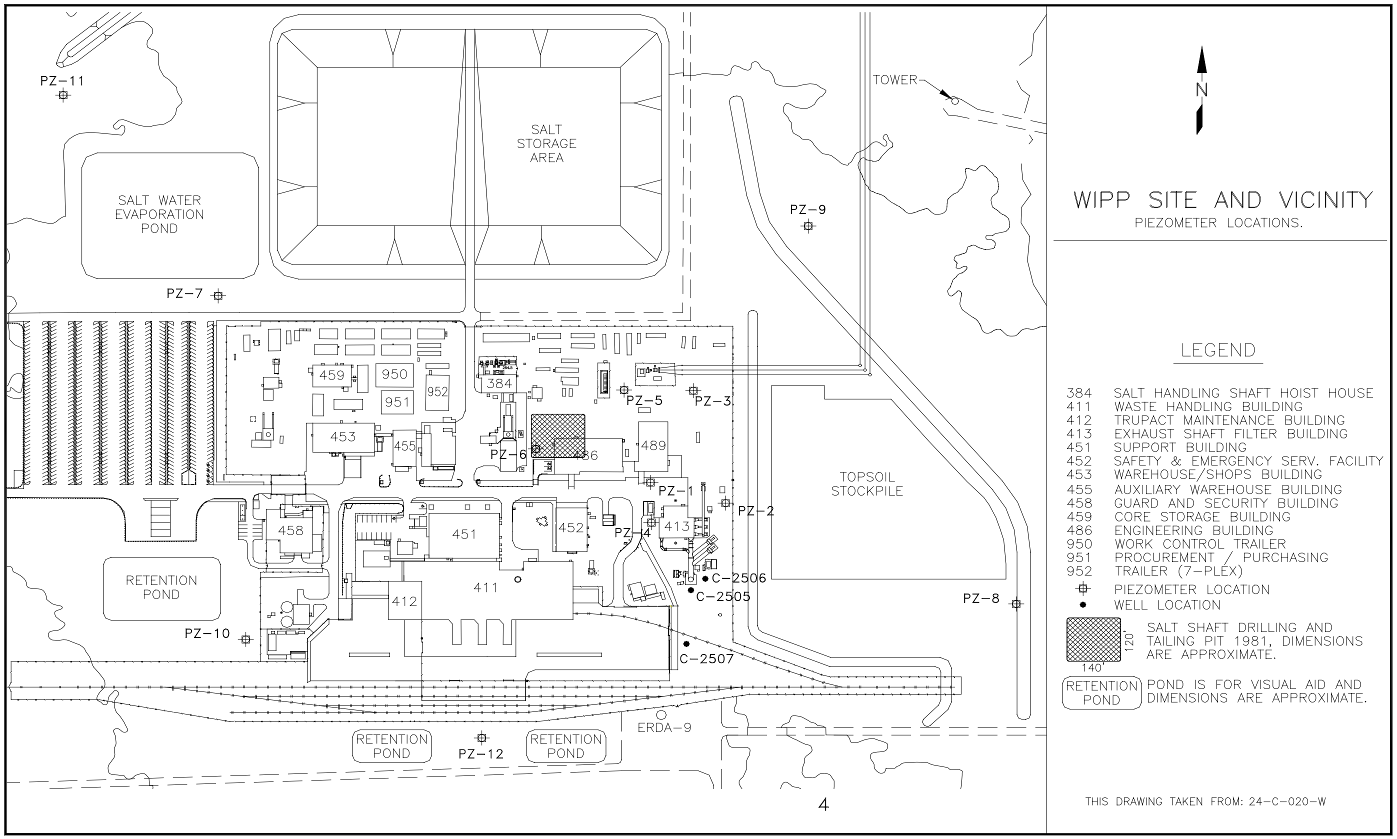

Figure 9-3
Locations of Piezometers PZ-1 Through PZ-12 and Wells C-2505, C-2506, and C-2507

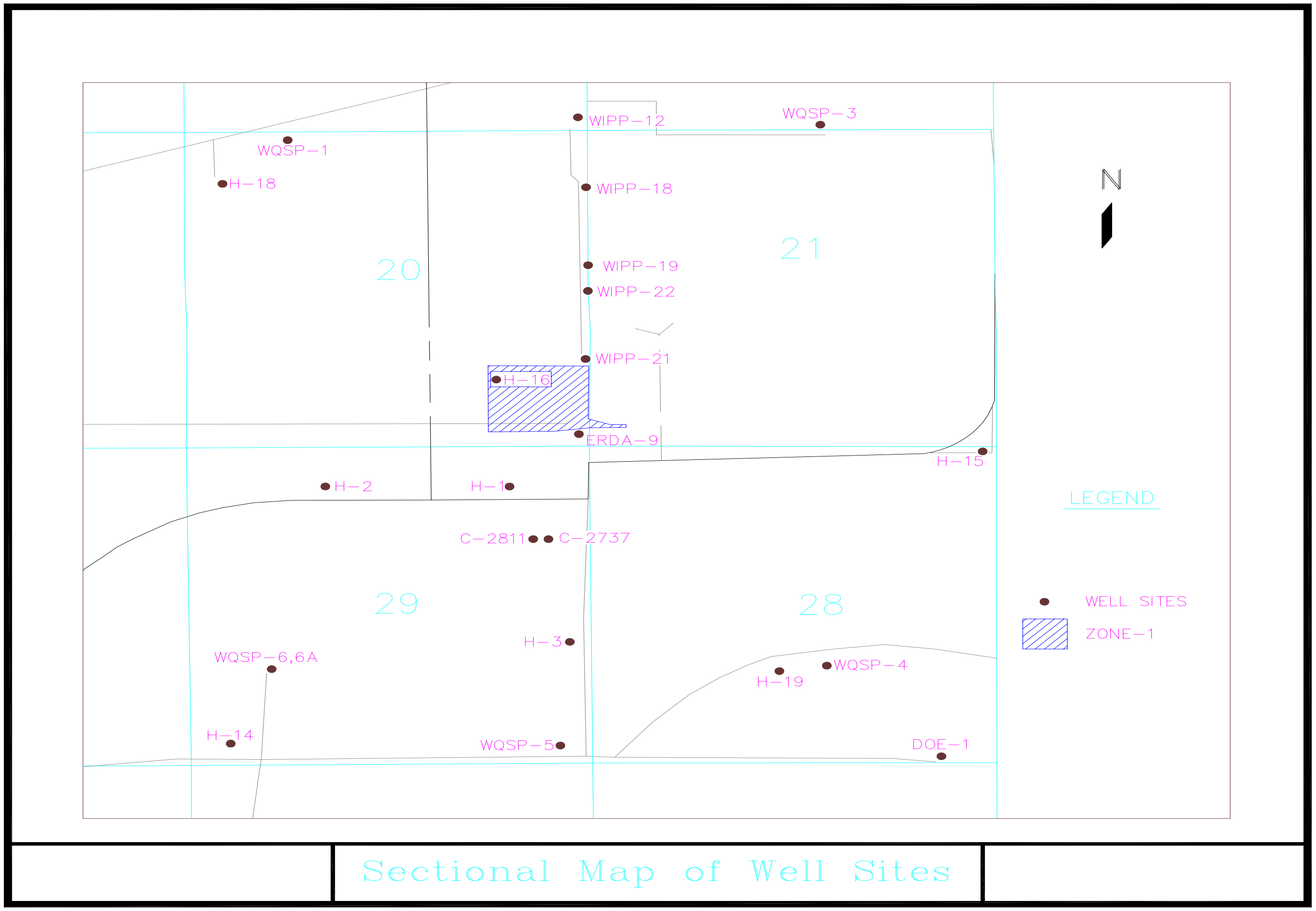

Figure 9-4
Section Map Providing Location of Wells C-2737 and C-2811 at the WIPP Site

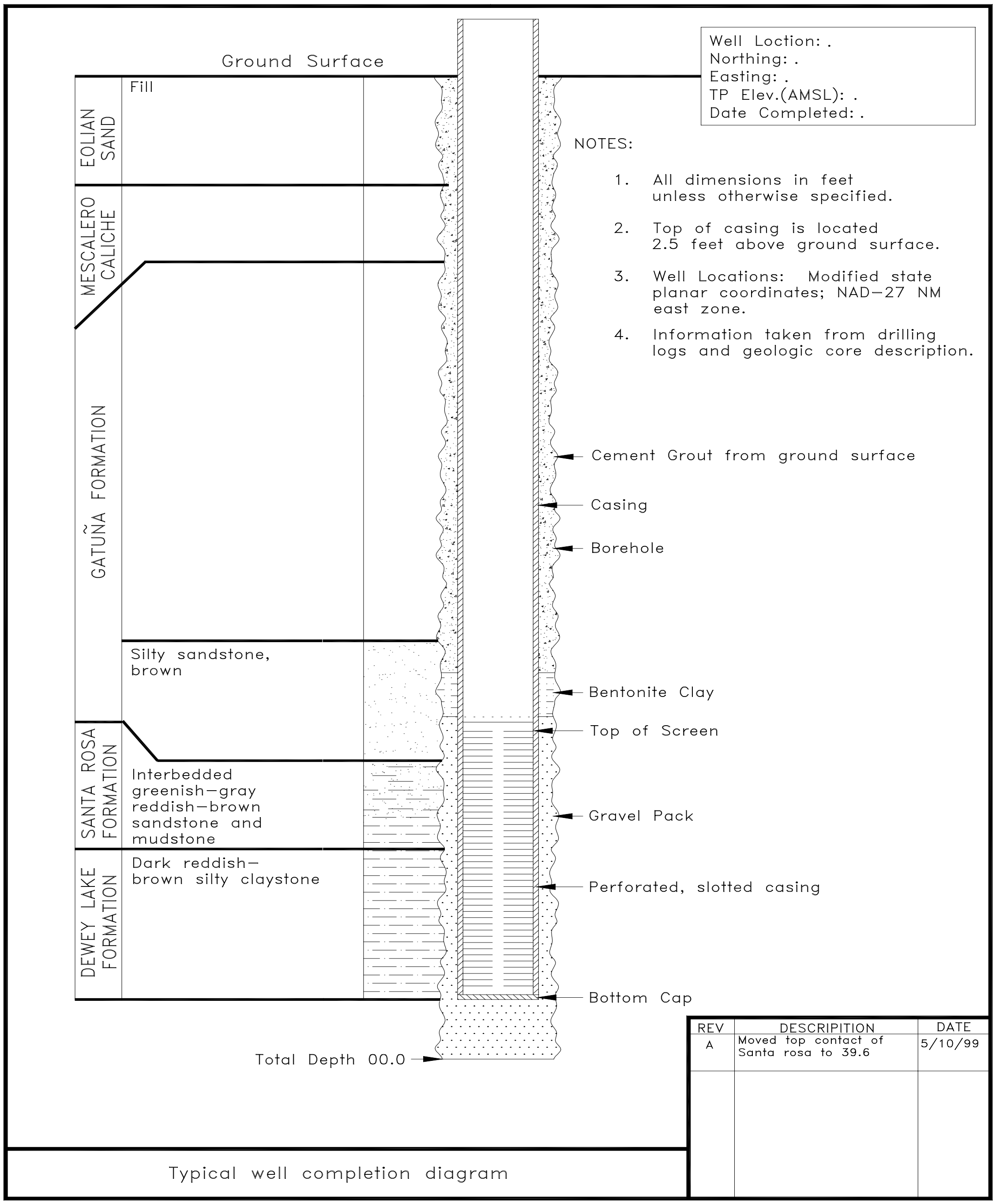

Figure 9-5
Typical Well Completion Diagram

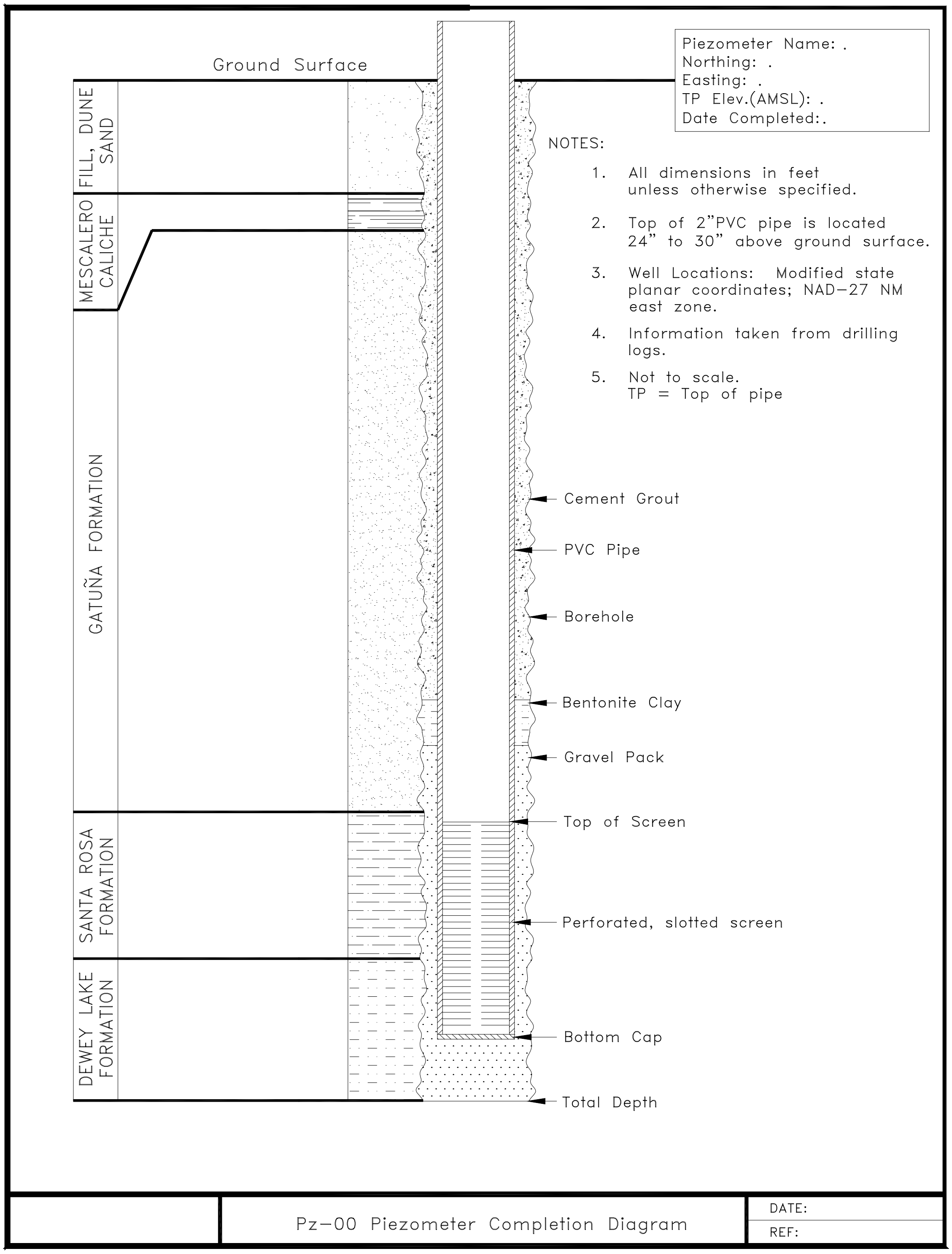

Figure 9-6
Typical Piezometer Completion Diagram

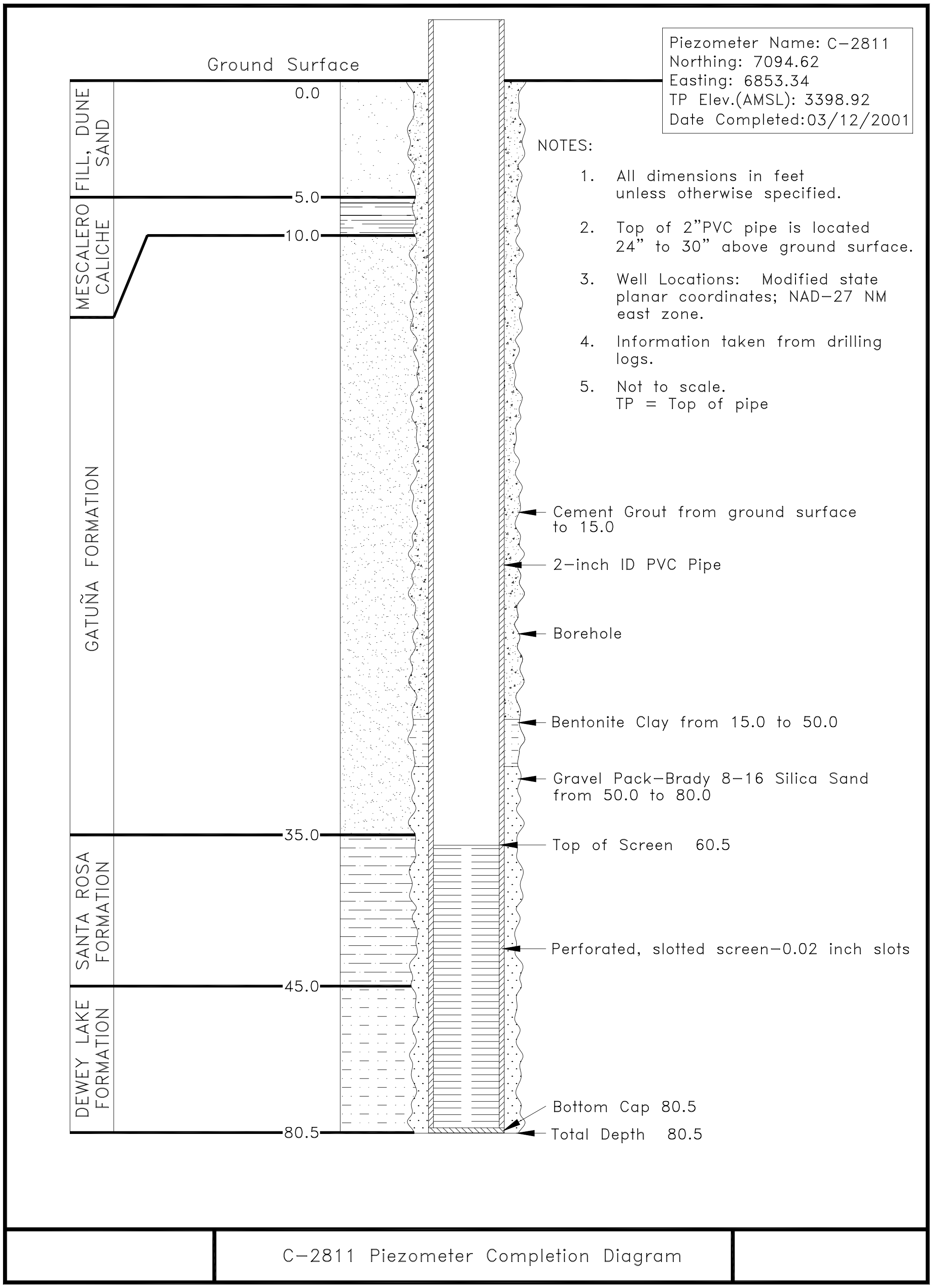

Figure 9-7
C-2811 Piezometer Completion Diagram

9.4 Water Chemistry

Water samples were collected and analyzed from three wells and eleven piezometers penetrating the perched groundwater horizon located in the Santa Rosa and upper Dewey Lake Formations at WIPP (PZ-8 is a dry hole: no samples collected). Samples were collected quarterly between February 1997 and October 1998, semiannually between October 1998 and October 2000, and annually beginning October 2000. The perched and anthropogenic water-chemistry data are used to determine changes in the water over time. Such changes are useful in understanding water sources, inflow rates, movement, and direction.

Table 9-3 provides TDS and water level measurements for the fifteen monitoring wells and piezometers (not including C-2811) collected in October 1997, February 2000, and October 2000.

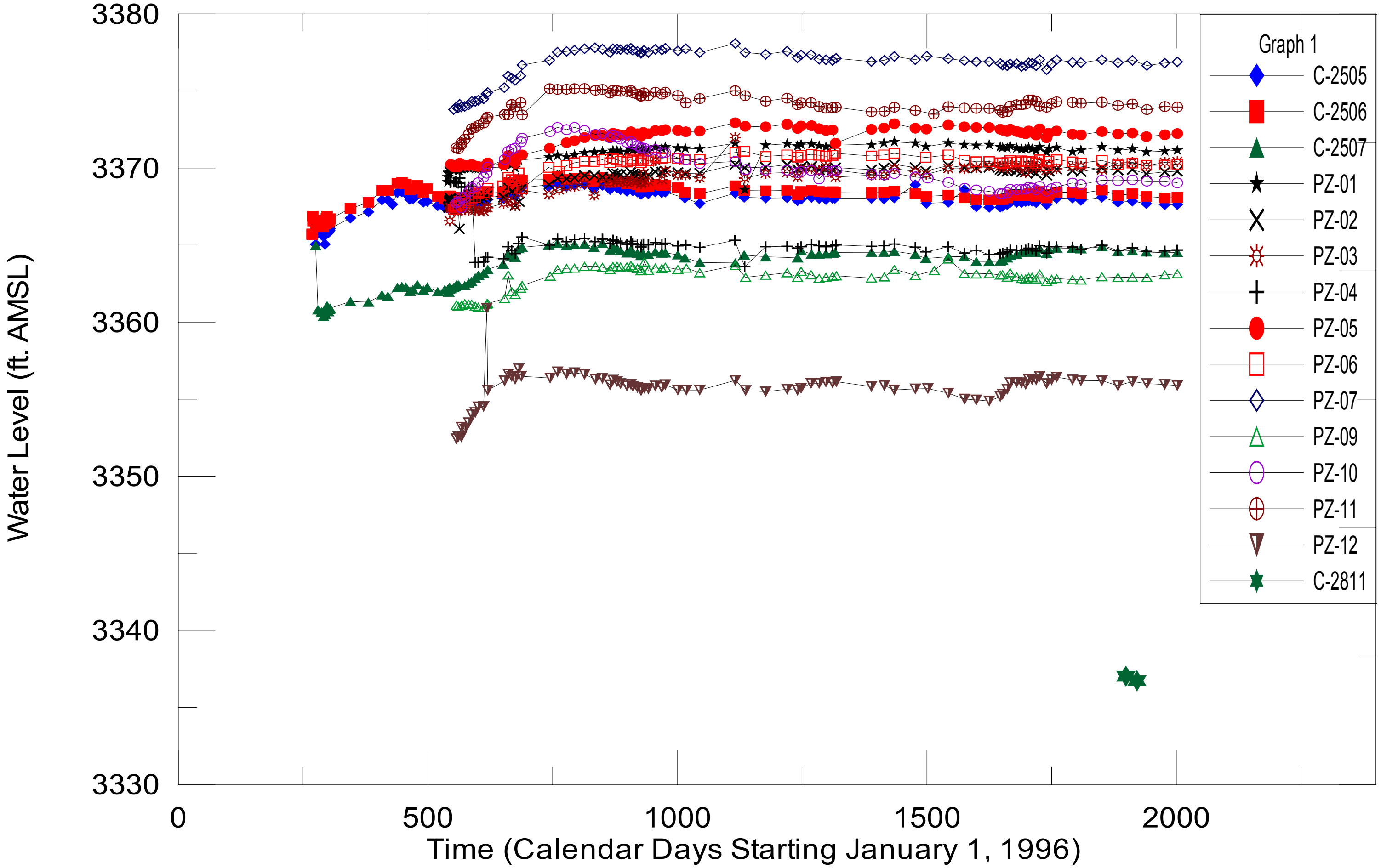

Figure 9-8
Water-Level Measurements Collected Between October 1996 and June 2001

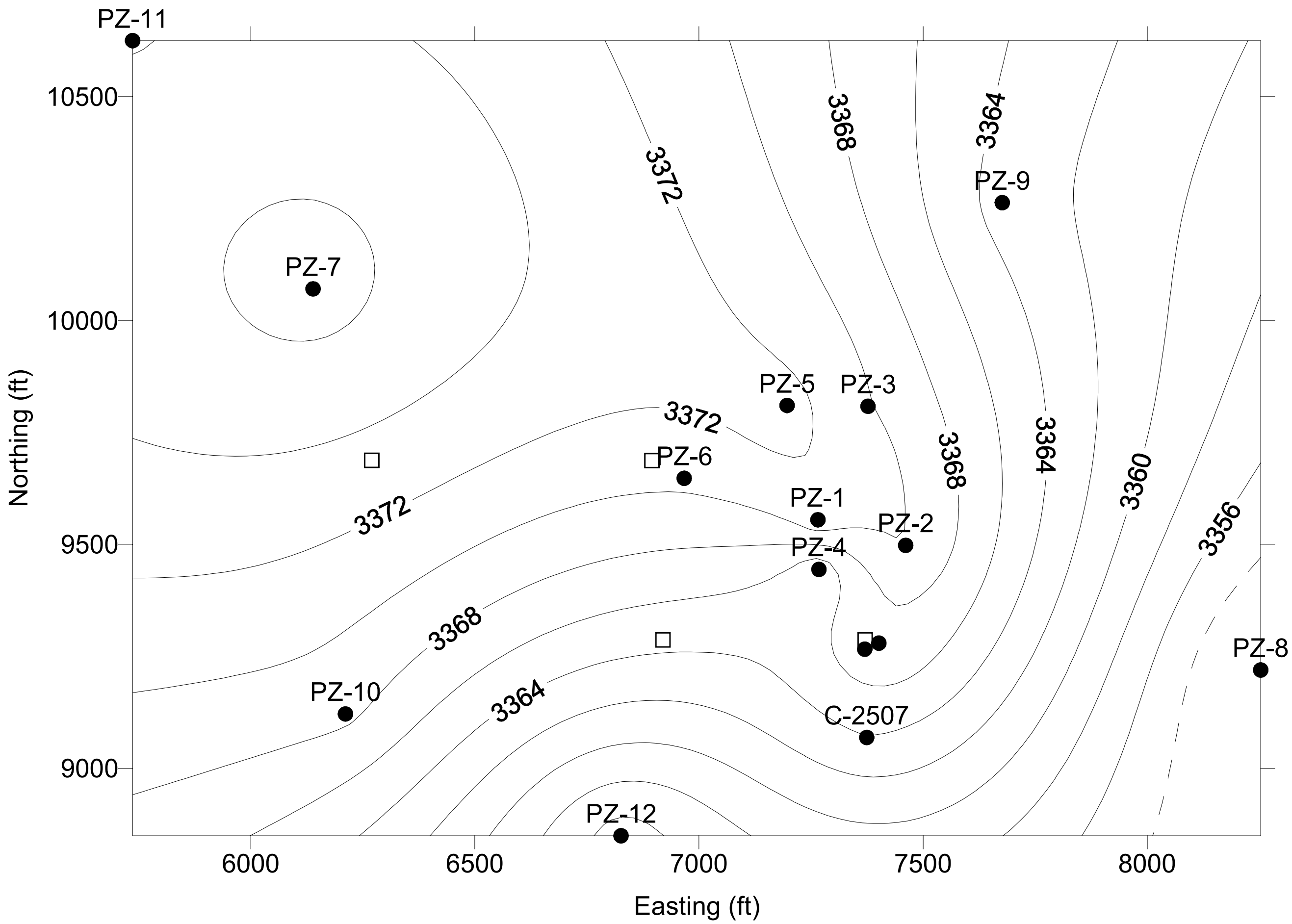

Figure 9-9
Contour Plot of the Potentiometric Surface in the Santa Rosa Formation: June 2000

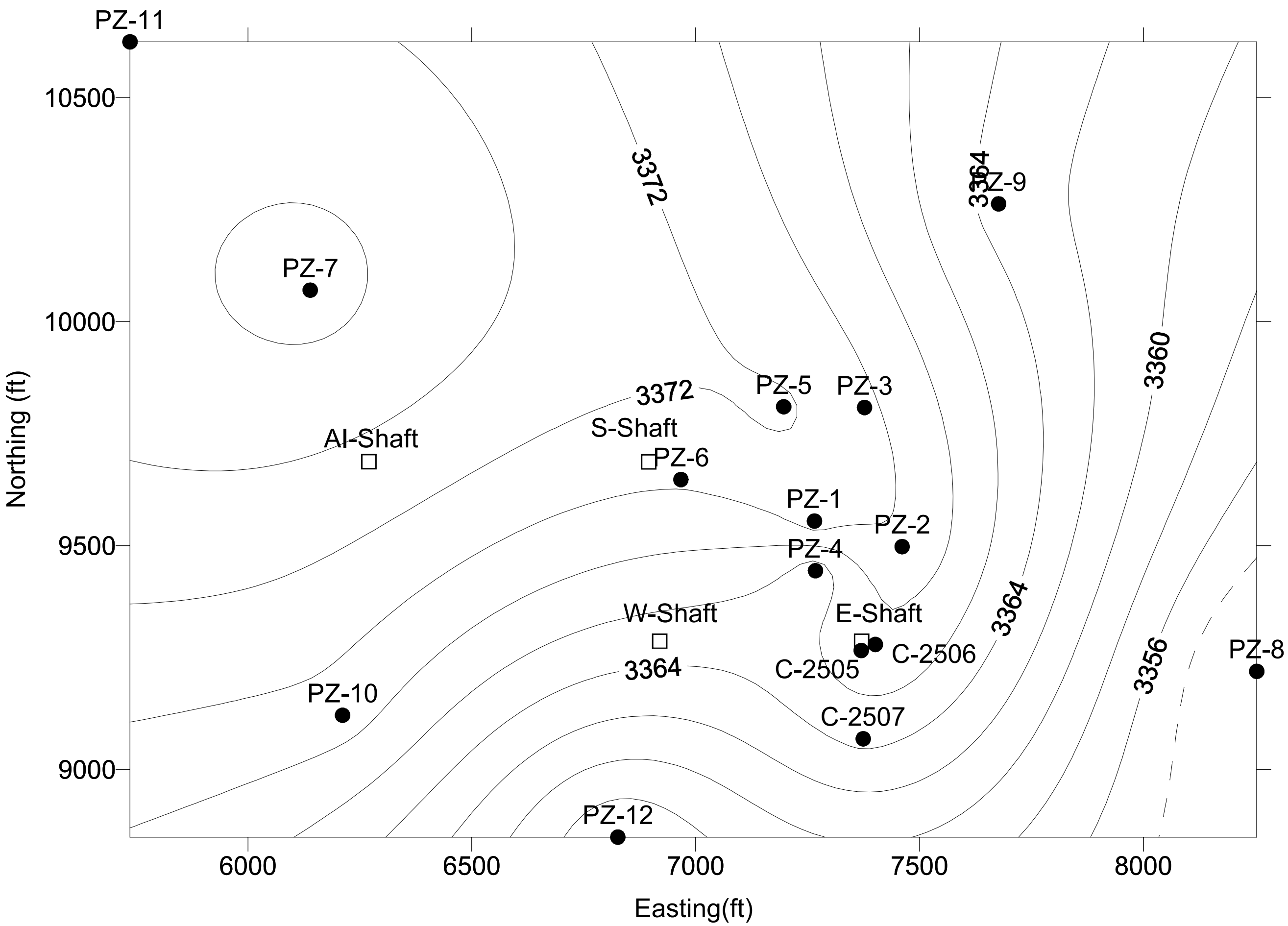

Figure 9-10
Contour Plot of Potentiometric the Surface in the Santa Rosa Formation: June 2001

Table 9-2
Spreadsheet used to generate Figures 9-9 and 9-10 contour maps; June 2000 and 2001

Location	X-coord. (feet)	Y-coord. (feet)	Z-coord. (feet-amsl)	Water Level (feet) 6/00	Water Level (feet) 6/01	Net Change (feet) 6/00 – 6/01
C-2505	7369.78	9266.10	3413.05	3367.45	3367.63	0.18
C-2506	7401.25	9279.58	3412.87	3367.93	3368.09	0.16
C-2507	7374.15	9069.04	3410.01	3363.94	3364.52	0.58
PZ-1	7265.34	9554.94	3413.41	3371.51	3371.16	-0.35
PZ-2	7461.05	9497.89	3413.42	3370.04	3369.79	-0.25
PZ-3	7377.09	9808.38	3416.15	3370.13	3370.43	0.30
PZ-4	7267.51	9444.17	3412.10	3364.38	3364.68	0.30
PZ-5	7196.50	9810.19	3415.31	3372.63	3372.24	-0.39
PZ-6	6967.02	9647.56	3413.49	3370.42	3370.25	-0.17
PZ-7	6139.11	10070.34	3413.99	3376.91	3376.89	-0.02
PZ-8	8253.00	9219.59	3418.27	3350.59*	3350.59*	0.00
PZ-9	7676.45	10262.84	3421.21	3363.15	3363.14	-0.01
PZ-10	6211.37	9121.53	3405.80	3368.49	3369.04	0.55
PZ-11	5736.63	10624.54	3418.95	3373.87	3373.96	0.09
PZ-12	6826.12	8849.59	3408.99	3354.89	3355.89	1.00
AI-Shaft	6269.91	9687.41				
S-Shaft	6894.89	9687.23				
W-Shaft	6919.89	9287.23				
E-Shaft	7370.39	9287.23				

* Estimated Value

Results of the water-quality sampling analysis from the Exhaust Shaft Hydraulic Assessment Program between February 1997 and October 2000 are presented in the supporting data document. The table contains both analytical results and statistical calculations providing information on the number of samples, the mean, standard deviation, and minimum and maximum values for the specific parameters monitored. With minor exception, charge-balance calculations fall in the range of ± 5 percent. Out of 236 samples, only thirteen samples fell outside the ± 5 percent range.

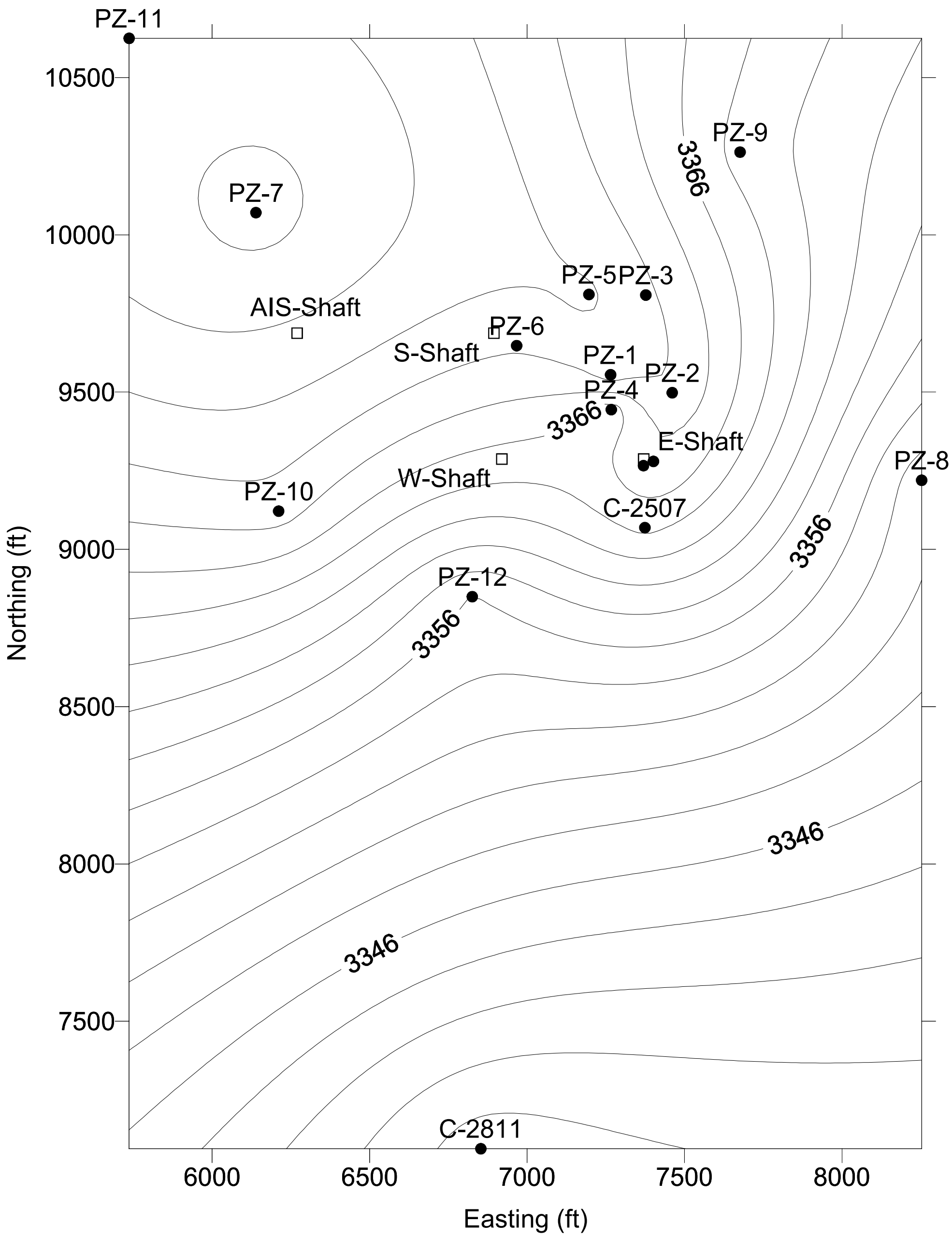

Figure 9-11
Contour Plot of the Potentiometric Surface in the Santa Rosa Formation Including C-2811

Table 9-3
List of Total Dissolved Solids Measurements for October 1997, February 2000 and October 2000

Name	TDS 10/97 mg/L	TDS 2/00 mg/L	TDS 10/00 mg/L
C-2505	4280	10600	10630
C-2506	6240	17000	15920
C-2507	3580	3770	4475
PZ-1	102000	60200	54000
PZ-2	25000	14600	11130
PZ-3	163000	168000	88400
PZ-4	40400	51400	42050
PZ-5	99300	71800	84800
PZ-6	27700	51400	55100
PZ-7	23900	47700	48000
PZ-8	No water	No water	No water
PZ-9	115500	118000	128400
PZ-10	2950	2430	2467
PZ-11	25350	72000	44250
PZ-12	3420	10700	9650

Figure 9-12 presents a modified Stiff diagram showing the variability in major-cation and anion ratio compositions. Two wells, PZ-10 and C-2507 have unique chloride signatures containing less than 60% chloride relative to carbonate and sulfate ions. All other monitoring wells have greater than 75% chloride. The unique signatures for these two wells suggest a low chloride source.

9.4.1 Total Dissolved Solids

Figure 9-13 is a plot of TDS. TDS values range from about 2,467 mg/L to 128,000 mg/L for samples collected in October 2000. The highest values are found in the northeastern portion of the site at PZ-3, PZ-5 and PZ-9. The lowest values are found at PZ-10 and C-2507.

Figures 9-14, 9-15, and 9-16 are contour maps of the water-level surface in the Santa Rosa superimposed on top of TDS contour maps for the Exhaust Shaft monitoring system for February 1997, February 2000, and October 2000. The contour maps indicate the highest TDS was originally located in the vicinity of PZ-3 and has shifted northeast toward PZ-9 Careful study of hydraulic data, water chemistry data, the history of the WIPP site shafts, and associated activities suggests that the fluid in the Santa Rosa Formation is augmented by focused and ongoing recharge of precipitation.

9.4.2 Chloride

Figure 9-17 is a plot of chloride concentrations. For October 2000 chloride values ranged from a maximum of 70,100 mg/L at PZ-9 mg/L to 48,700 mg/L at PZ-5 and 48,400 at PZ-3. Moving down gradient hydraulically the values decrease. The lowest chloride values are located at PZ-10 with 526 mg/L and C-2507 with 1560 mg/L. High chloride values are associated with the dissolution of halite and sylvite. PZ-7 and PZ-11 located hydraulically up gradient from PZ-3, PZ-5 and PZ-9 are recharged by surface runoff from the Salt Storage Area which drains into the Salt Water Evaporation Pond. Piezometer PZ-10 and well C-2507 are both located near retention ponds, which are low in chlorides.

9.4.3 Sulfate

Figure 9-18 is a plot of sulfate concentrations. For October 2000 Sulfate values range from 3090 mg/L at PZ-9 and 1850 mg/L at PZ-3 to 754 mg/L at PZ-10. Sulfate is most commonly associated with the dissolution of gypsum, $CaSO_4$ (H_2O) and anhydrite, $CaSO_4$. Both evaporites are found present at the Salt Storage Area (Figure 9-3).

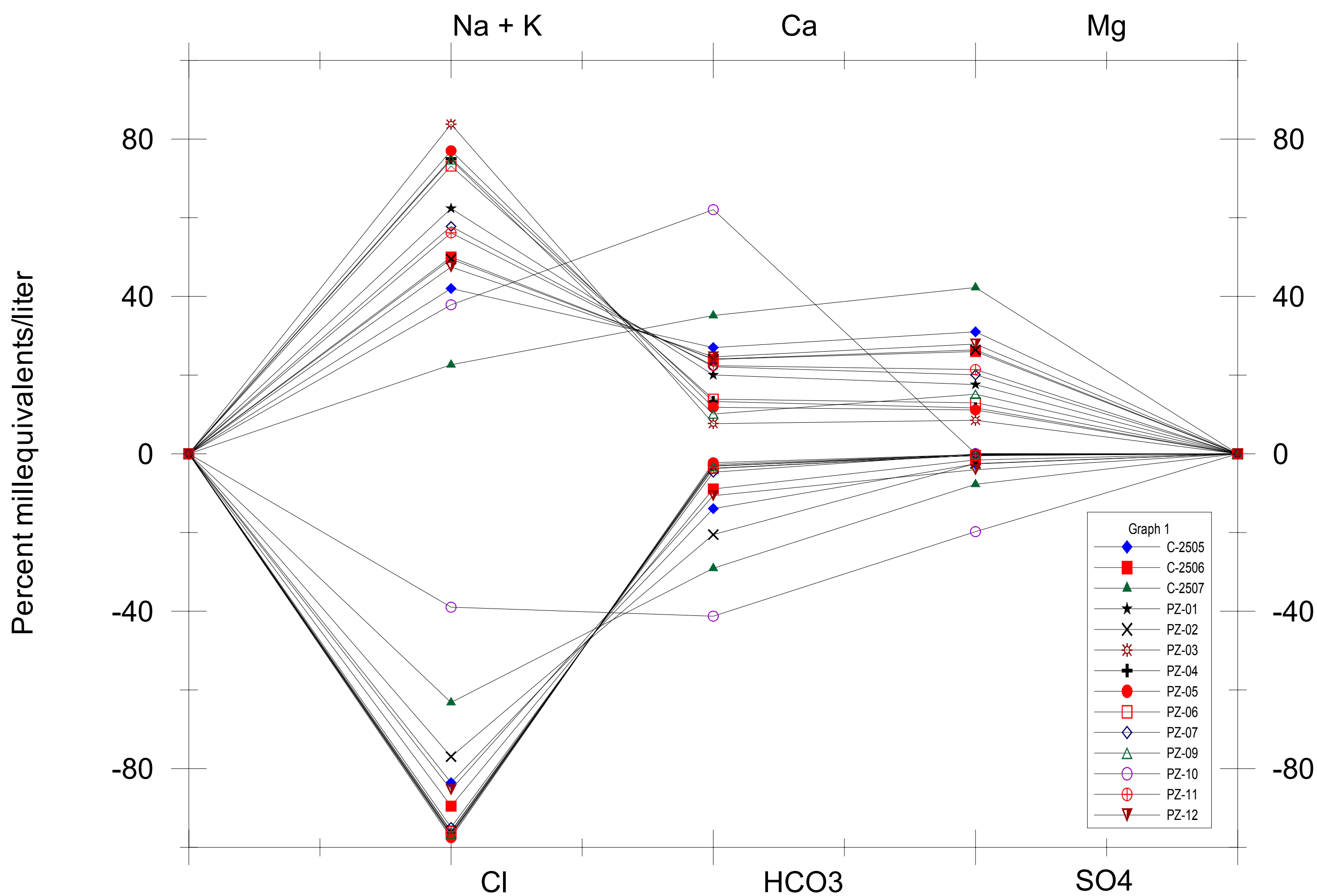

Figure 9-12
Modified Stiff Diagram Showing Percentage Major-Ion Composition of Perched Groundwater

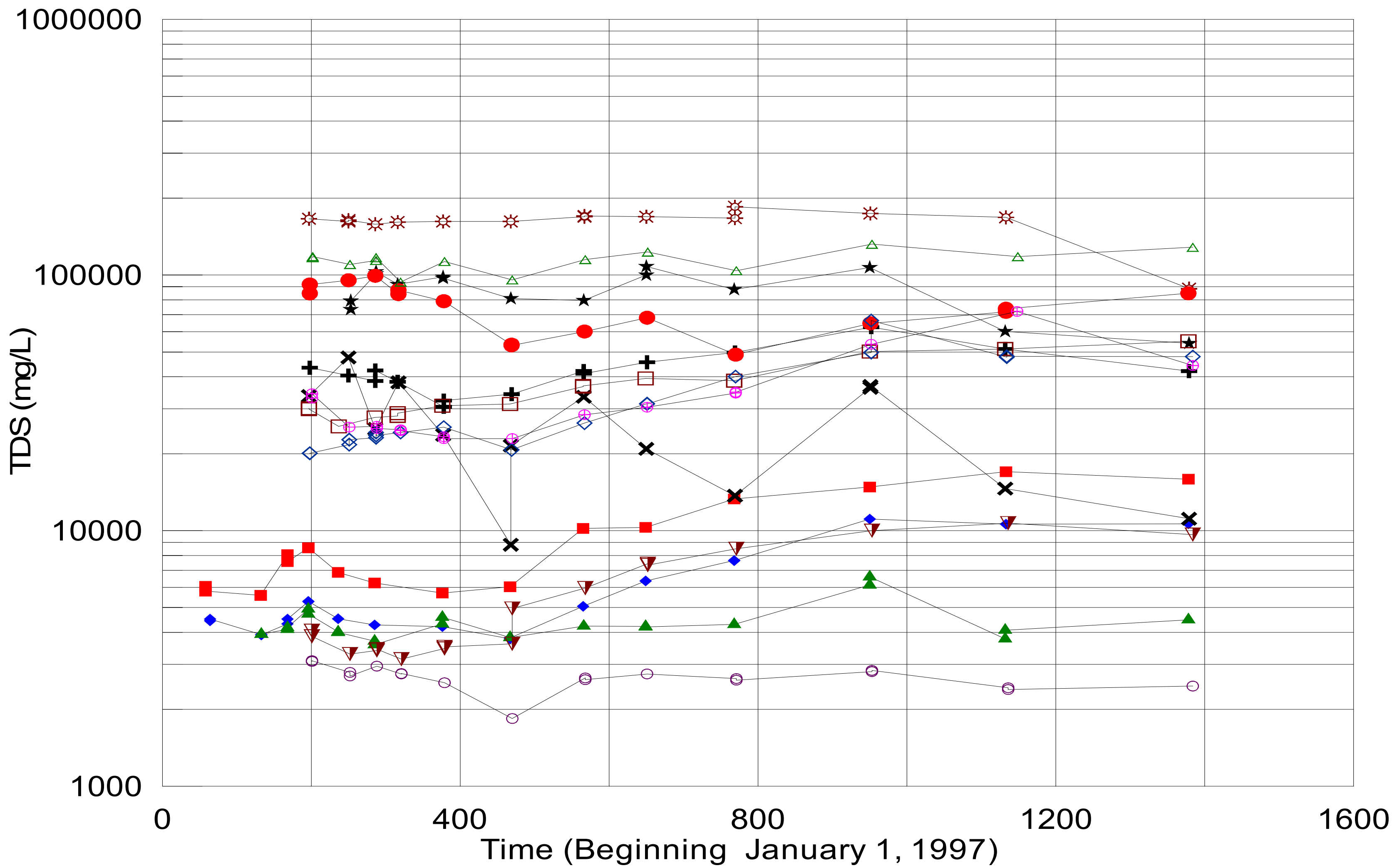

Figure 9-13
Linear Plot of Total Dissolved Solids: February 1997 – October 2000

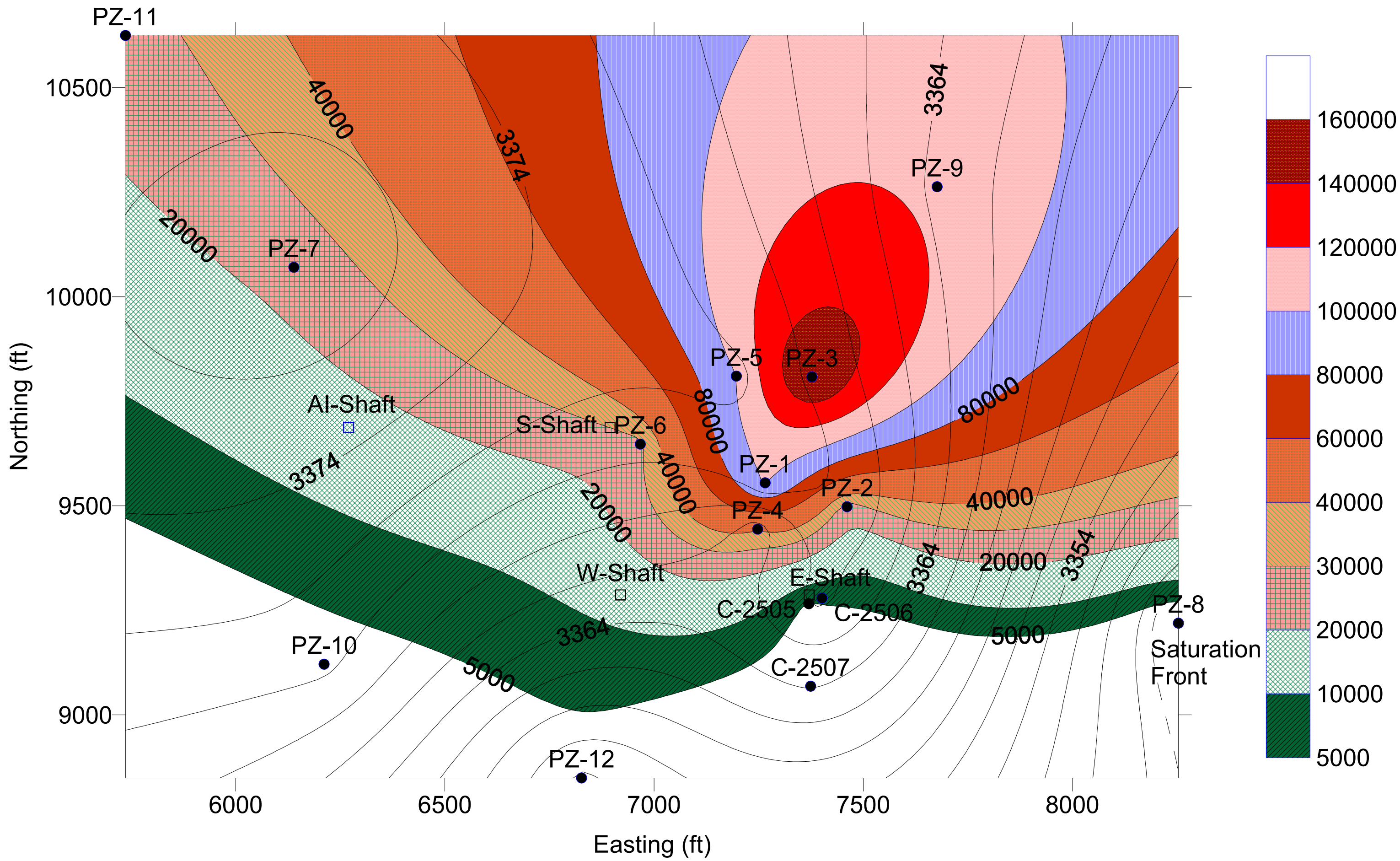

Figure 9-14
Water-Level Elevation and Water-Quality (Total Dissolved Solids) Contour Map: February 1997

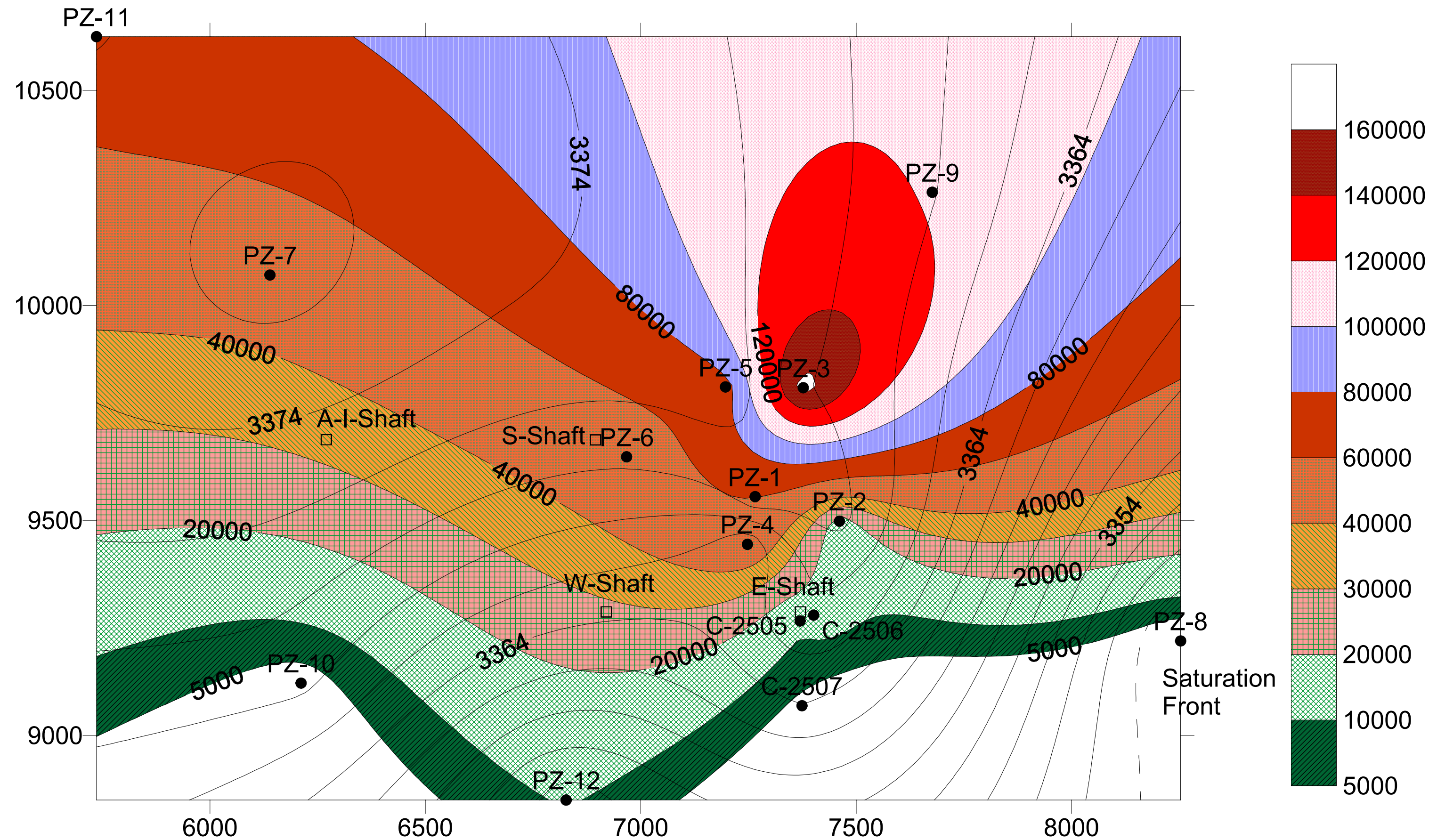

Figure 9-15
Water-Level Elevation and Water-Quality (Total Dissolved Solids) Contour Map: February 2000

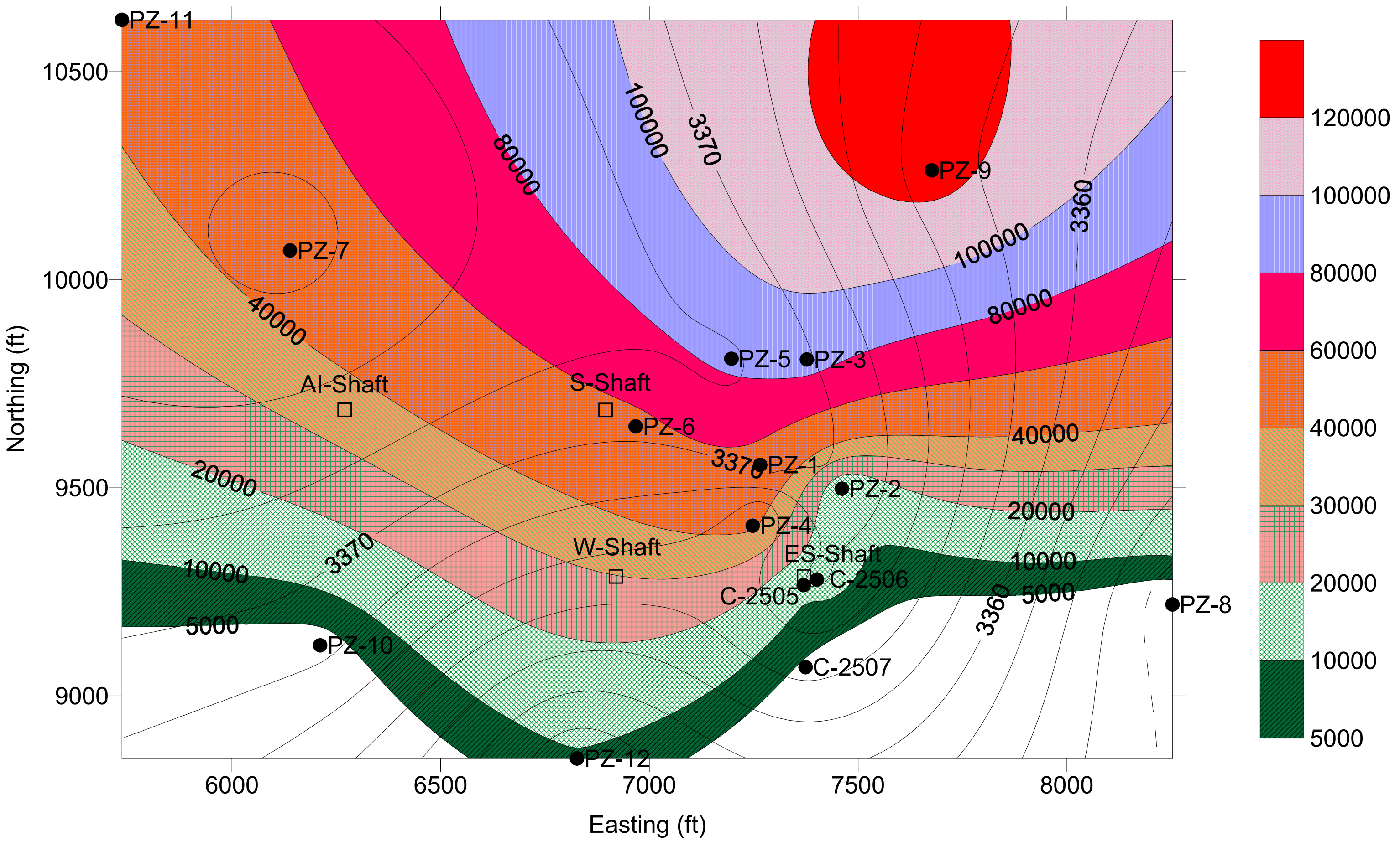

Figure 9-16
Water-Level Elevation and Water-Quality (Total Dissolved Solids) Contour Map: October 2000

9.4.7 Nitrate

Figure 9-22 is a plot of nitrate concentrations. The highest values are found at PZ-12, PZ-6, C-2507 and C-2506 and C-2505. Nitrates are commonly associated with fertilizers in farming, nitrogenous organic waste that tends to concentrate in places where large numbers of animals are confined, and leaky septic systems. PZ-12, which has the highest concentration of nitrate and C-2507 are located near retention ponds frequented by birds and local wildlife (Figure 9-3). C-2505 and C-2506 are located adjacent to the Exhaust Shaft. The disturbed zone around the shaft liner, as indicated by seepage cracks, and activities associated with the shaft may give rise to higher levels of nitrate.

9.4.8 Metals

- Figure 9-19 is a plot of selenium concentrations. Selenium is typically sympathetic with sulfate variation as selenium substitutes for sulfur in gypsum and other sulfate minerals.
- Figure 9-20 is a plot of iron concentrations. These values are consistent with the values collected over the past two years with little or no significant change in the concentration levels.
- Figure 9-21 is a plot of chromium concentrations. There is no distinct source of chromium known that would explain the results at C-2507 relative to the other wells.
- Figure 9-23 is a plot of mercury concentrations.
- Figure 9-24 is a plot of cadmium concentrations.
- Figure 9-25 is a plot of lead concentrations.
- Figure 9-26 is a plot of silver concentrations.

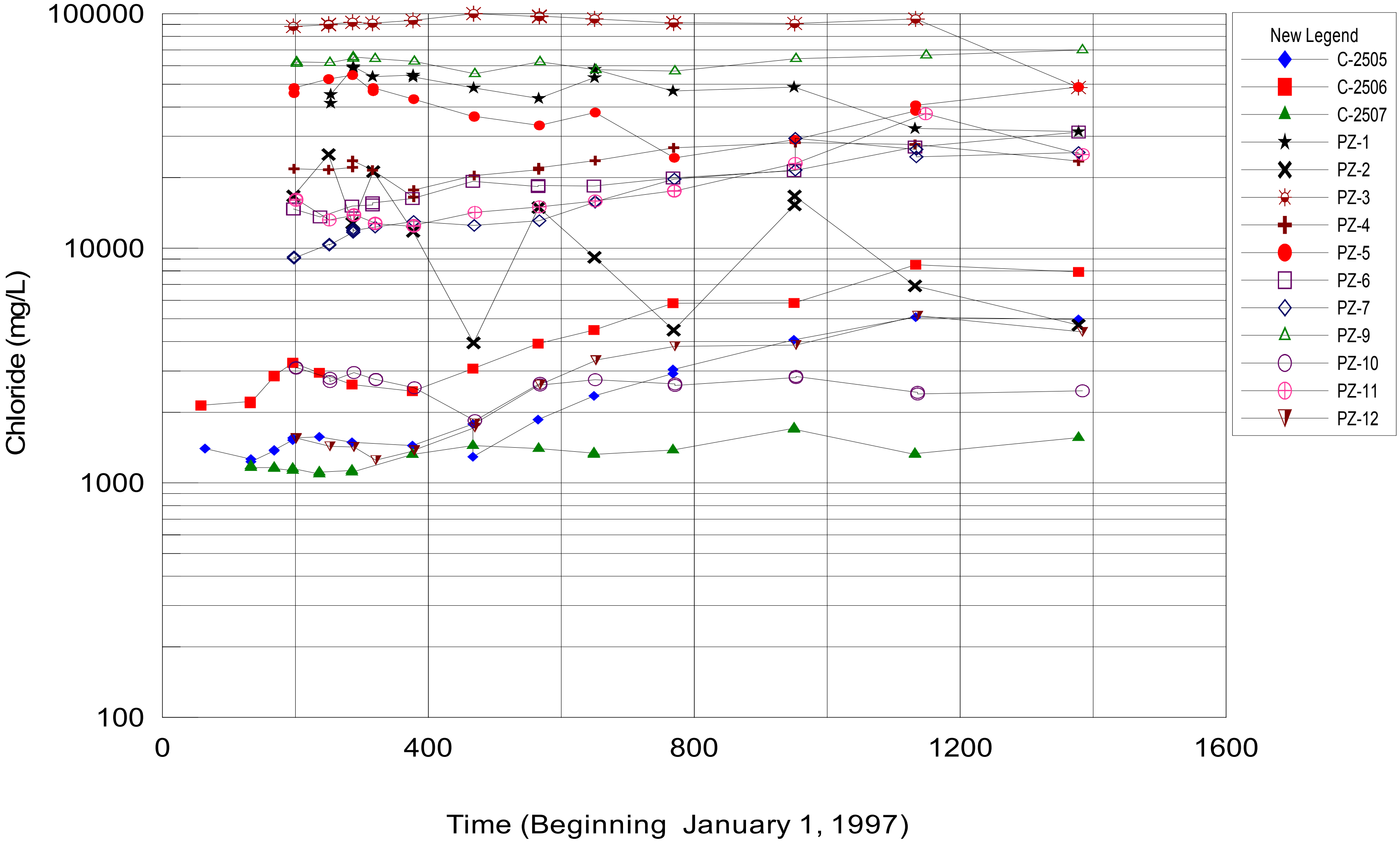

Figure 9-17
Semilog plot of Chloride: February 1997 – October 2000

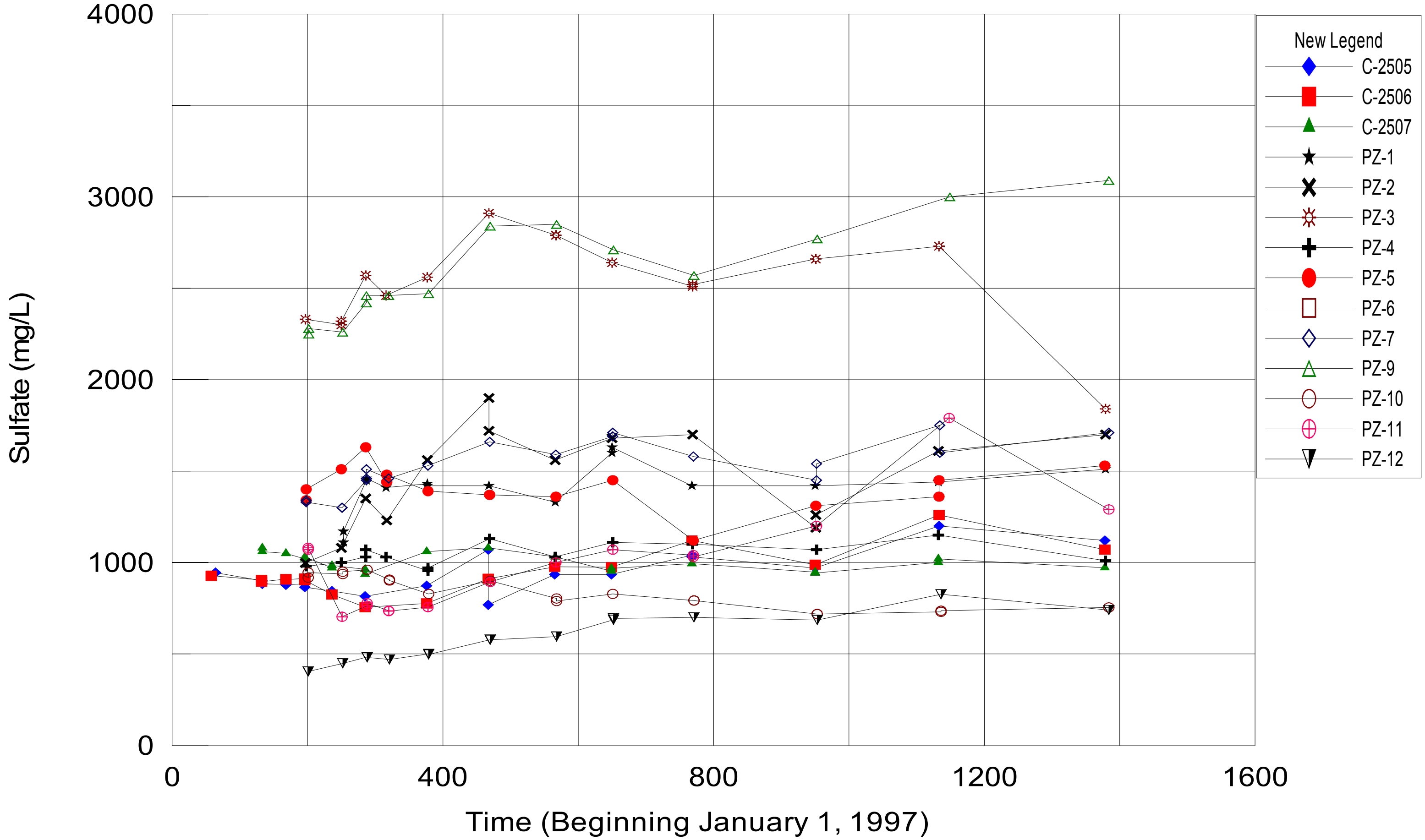

Figure 9-18
Linear Plot of Sulfate: February 1997 – October 2000

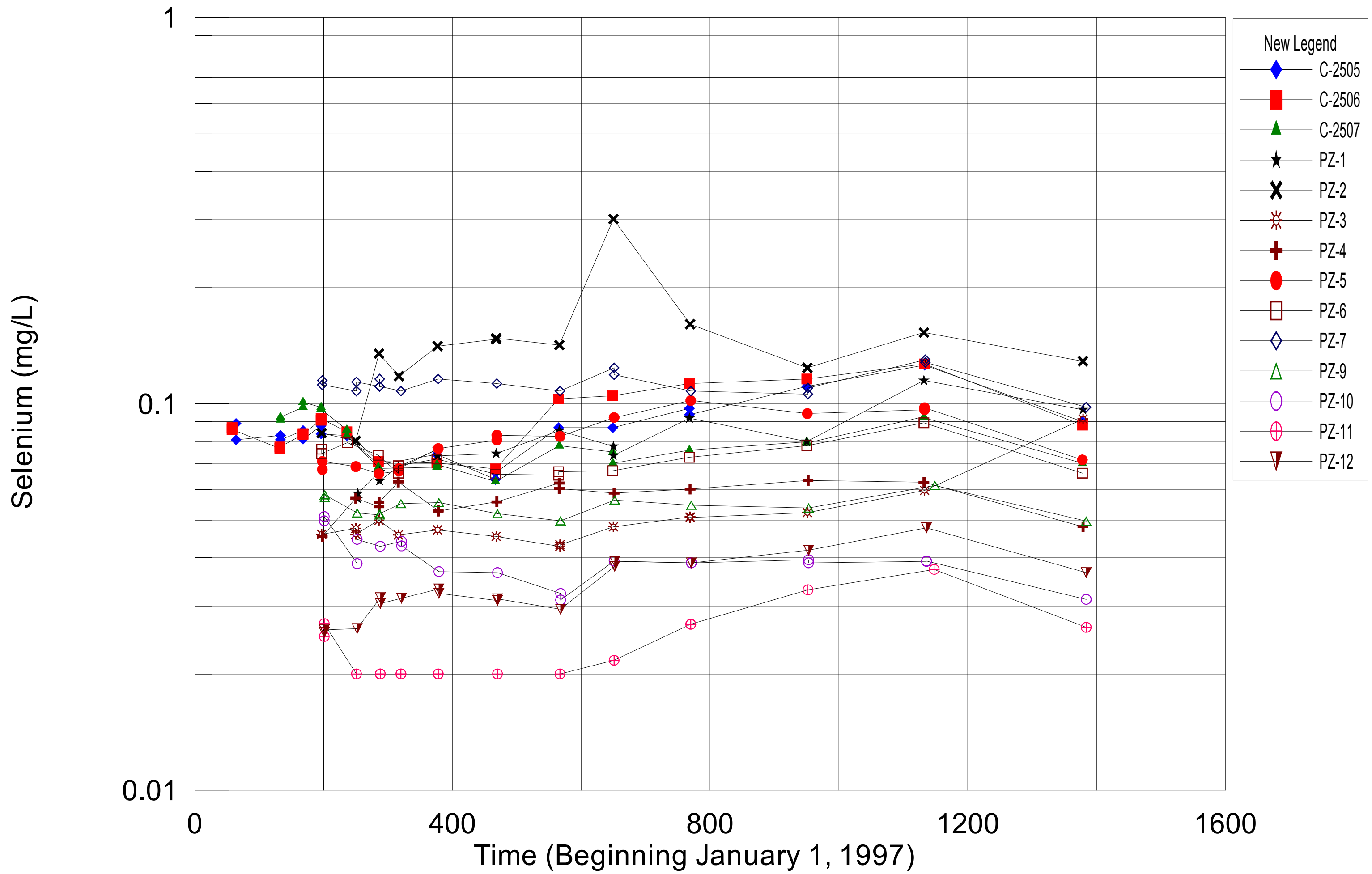

Figure 9-19
Semilog plot of Selenium: February 1997 – October 2000

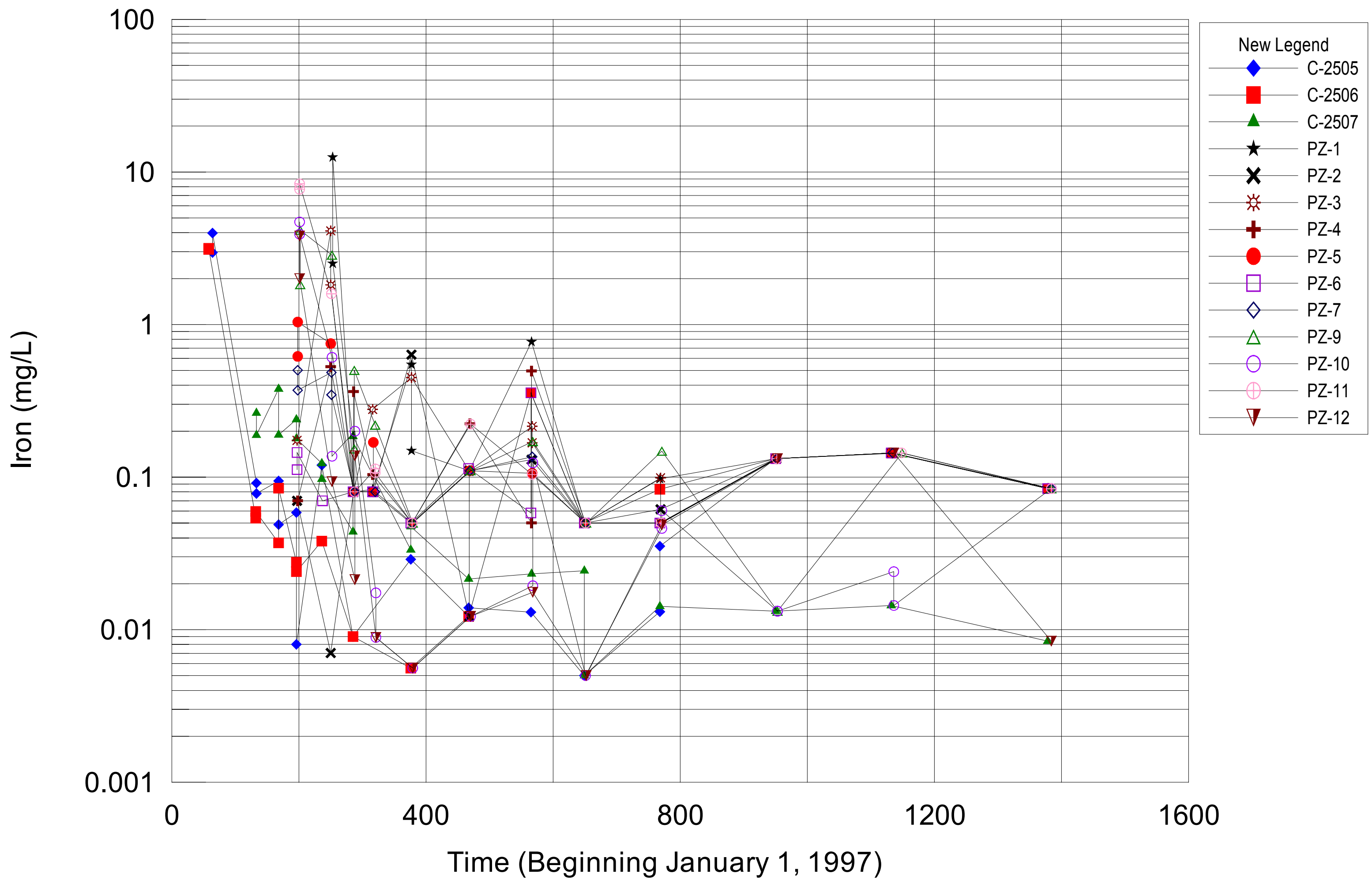

Figure 9-20
Semilog Plot of Iron: February 1997 – October 2000

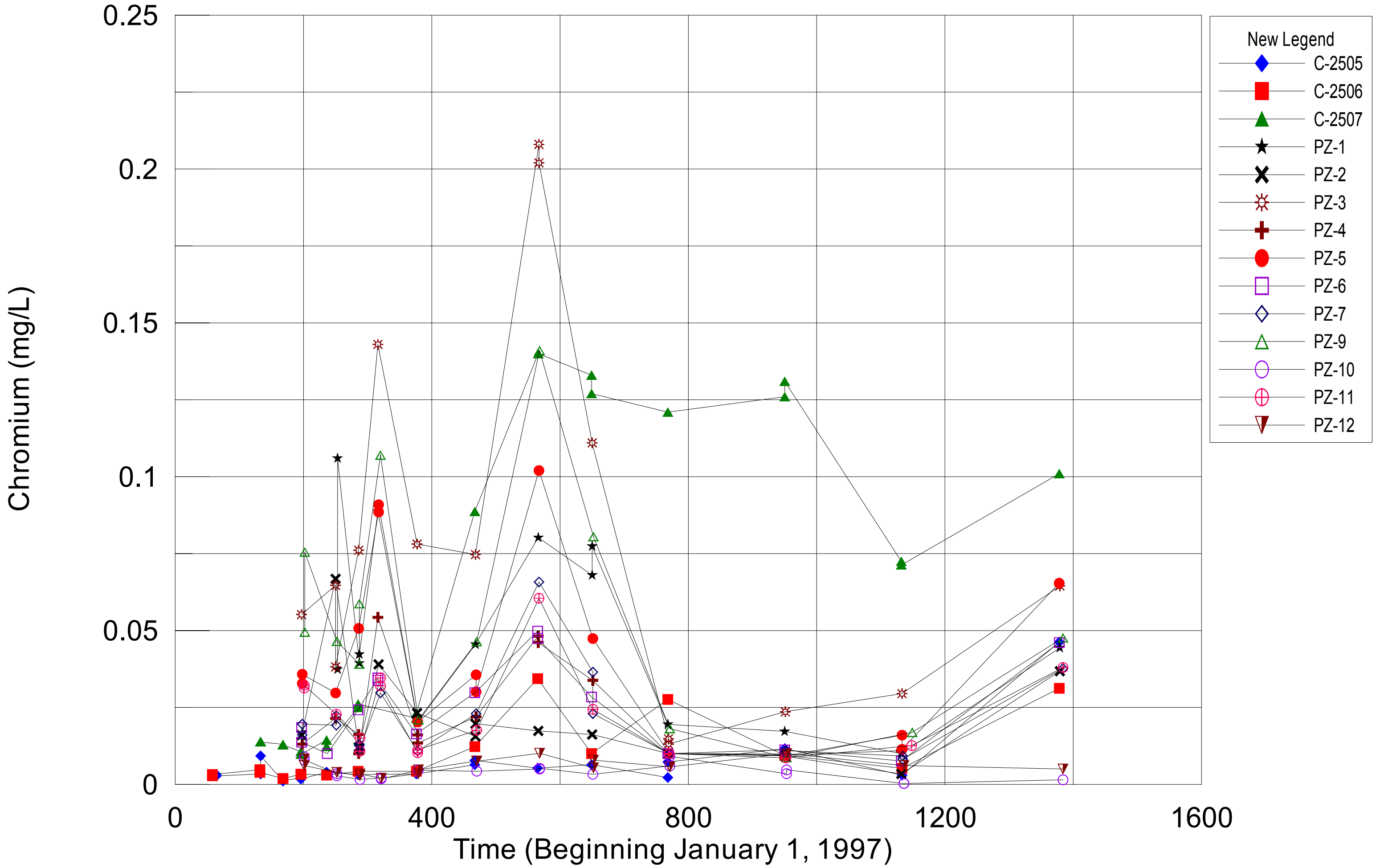

Figure 9-21
Linear Plot of Chromium: February 1997 – October 2000

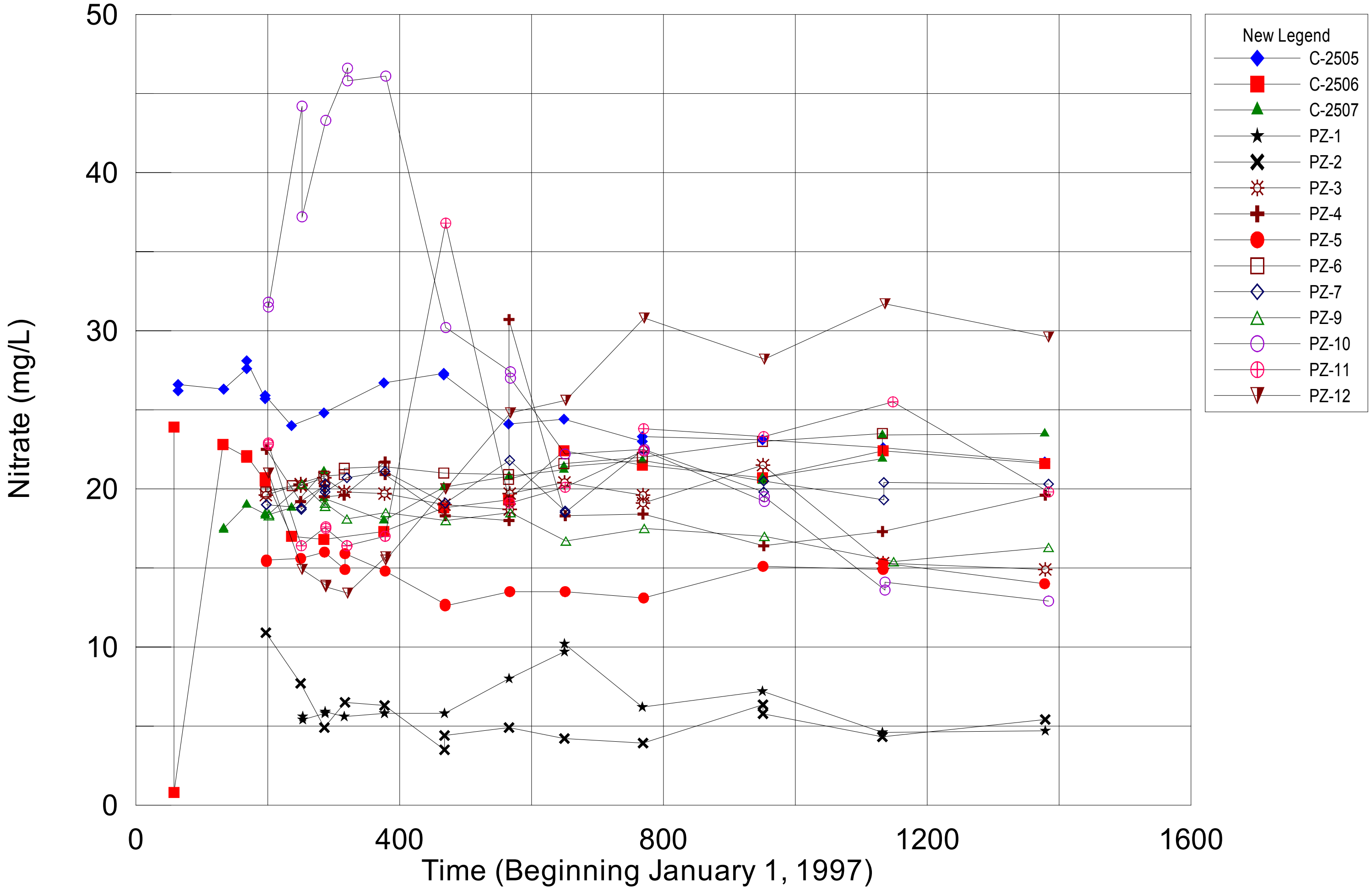

Figure 9-22
Linear Plot of Nitrate: February 1997 – October 2000

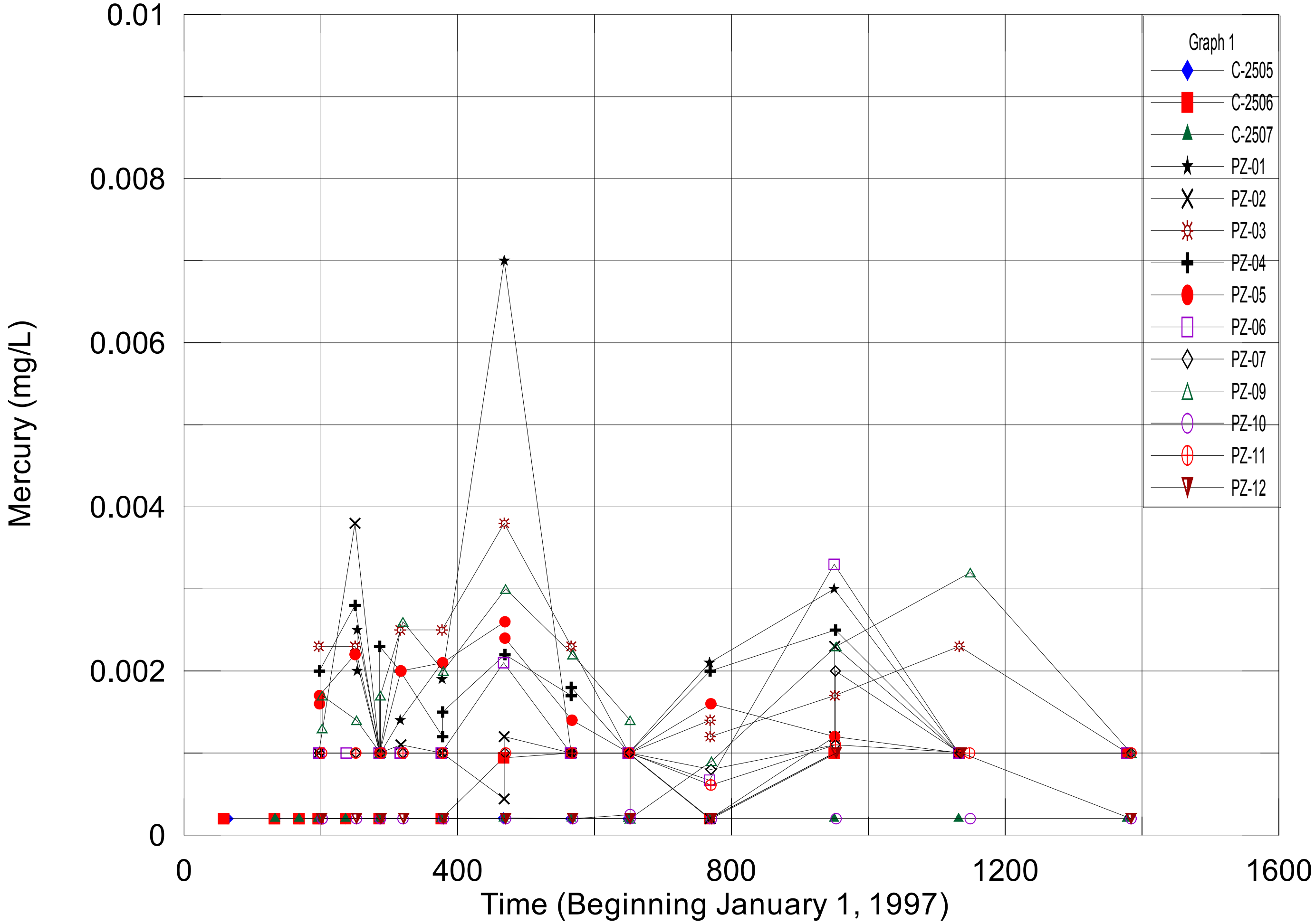

Figure 9-23
Linear Plot of Mercury: February 1997 – October 2000

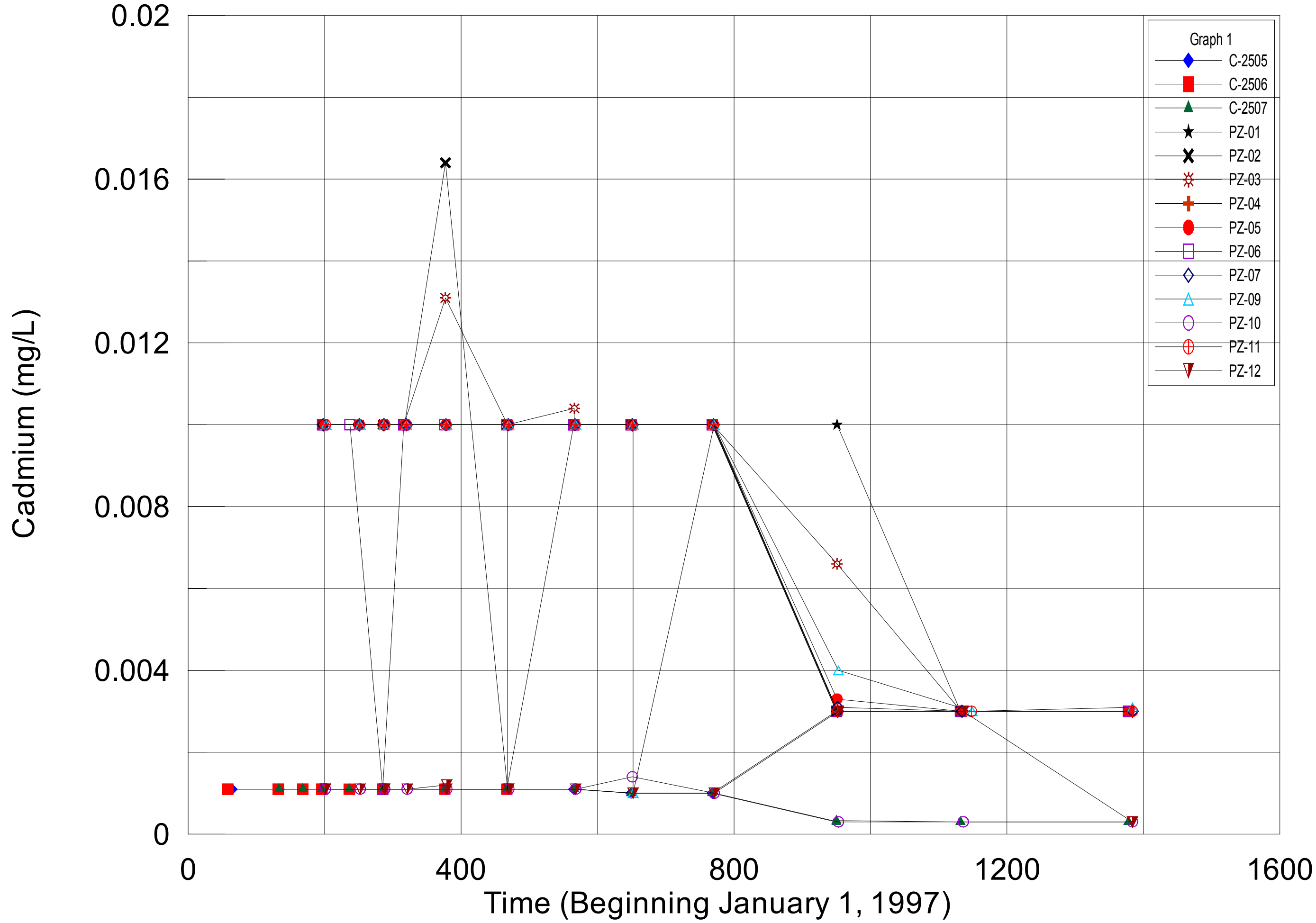

Figure 9-24
Linear Plot of Cadmium: February 1997 – October 2000

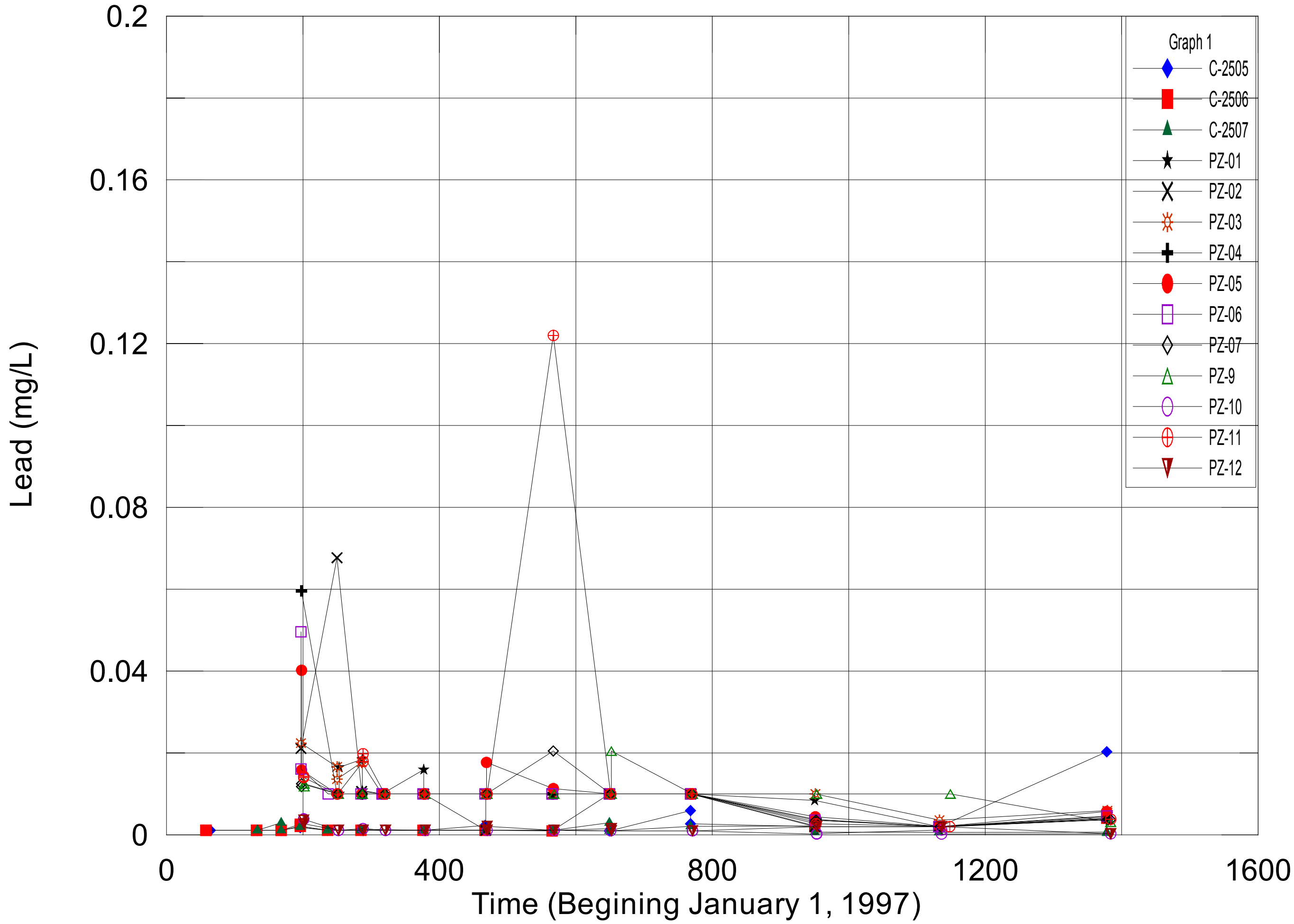

Figure 9-25
Linear Plot of Lead: February 1997 – October 2000

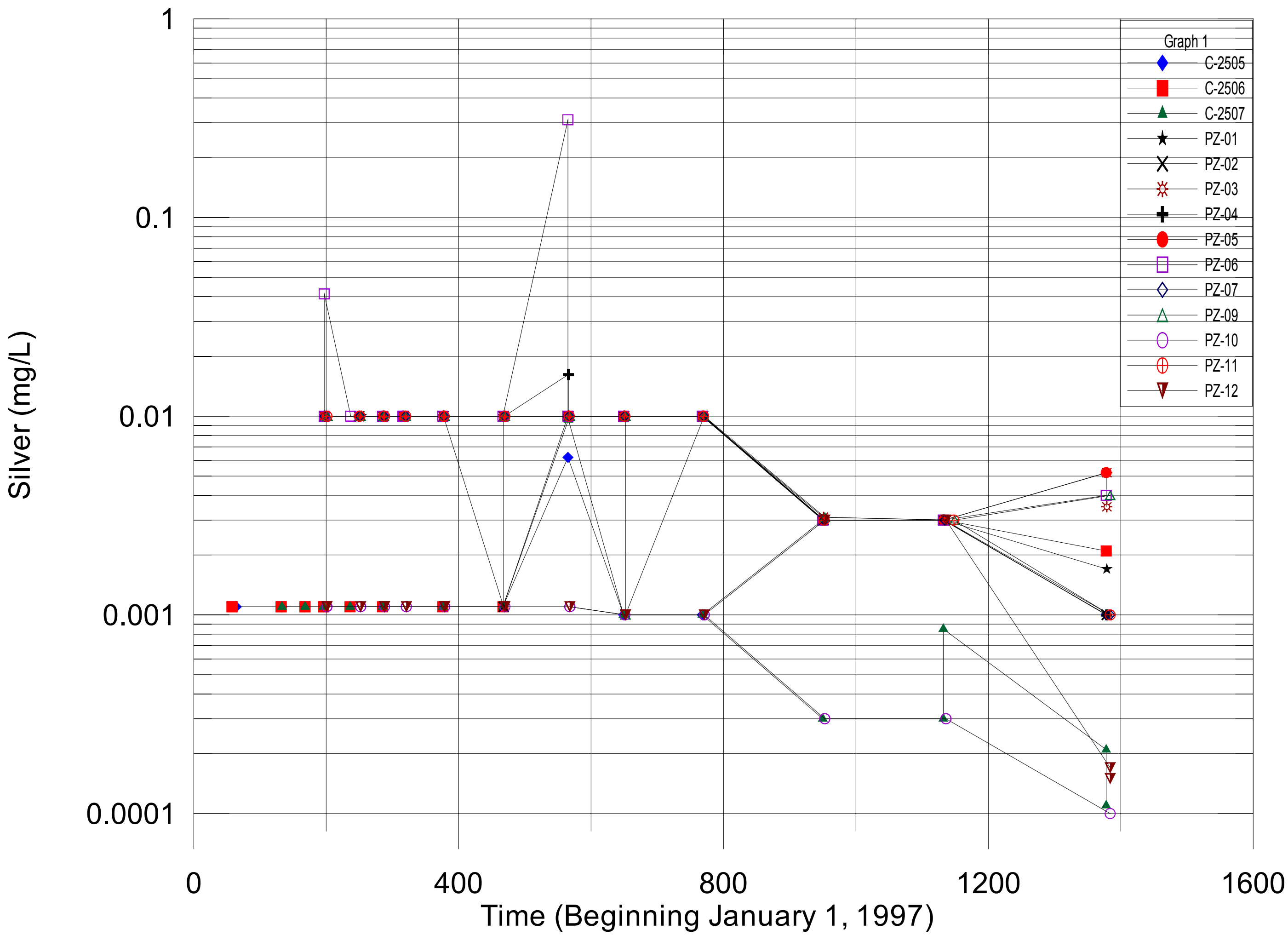

Figure 9-26
Semilog Plot of Silver: February 1997 – October 2000

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10.0 Summary

At the inception of the WIPP project, criteria were developed that address the requirements for the design of WIPP (DOE, 1984). These criteria, in the form of design requirements, pertain to all aspects of the mined facility and its operation as a pilot plant for the demonstration of technical and operational methods for permanent disposal of CH and remote handled (RH) TRU waste. In 1994, as WIPP developed and the focus moved toward the permanent disposal of TRU waste, these design requirements were reassessed and replaced by a new set of requirements called system design descriptions (SDD). Table 10-1 shows the comparison of these design requirements with conditions actually observed in the underground from July 2000 through June 2001.

Fracture development in the roof is primarily caused by the concentration of compressive stresses in the roof beam and is influenced by the size and shape of the excavation and the stratigraphy in the immediate vicinity of the opening. Pillar deformations induce lateral compressive stresses into the immediate roof and floor. With time the buildup of stress causes differential movement along stratigraphic boundaries. This differential movement is identified as offsets in observation boreholes and is indicated by the bends in failed rock bolts. Large strains associated with lateral movements can induce fracturing in the roof, which is frequently seen near the ribs. This scenario of roof deterioration, combining compressive stresses, horizontal offsetting, and large strains associated with lateral movements, is substantiated by earlier observations of similar roof deterioration in SPDV Room 1, SPDV Room 2, and the E140 drift between S1000 and S1950.

Normal drift and room maintenance continued during this reporting period with rib, roof, and floor scaling and trimming in various locations, and rock bolting and wire mesh installation as needed. Supplemental ground support systems consisting of cable slings and welded wire mesh were installed in S1600 drift within Panel 1.

New convergence point pairs were installed in the access drifts to Panel 2, and in various locations throughout the repository to replace mined out instruments. Entry was made into the deactivated Northern Experimental Area to assess the ground conditions to use the area for salt disposal. Remote convergence monitoring continues at selected locations east of E140 Drift. All accessible areas of the underground are connected to data loggers or are monitored manually.

Table 10-1
Comparison of Excavation Performance to System Design Requirements

Requirement	Comments
“The lining shall be designed for a hydrostatic pressure. . . .”	Water pressure observed on piezometers located behind the shaft keys in the Waste Shaft and the Exhaust Shaft remains below design levels.
“The key shall be designed to resist the lateral pressure generated by salt creep.”	Geomechanical data from the Waste Shaft indicate that the shaft is structurally stable. Extensometer data indicate that closure of all the shafts remains within design requirements. Data from the Air Intake Shaft indicate it is performing within design requirements[a,b]. Visual inspections of the shaft keys indicate that they are performing satisfactorily.
“The key shall be designed to retain the rock formation and will be provided with chemical seal rings and a water collection ring with drains to prevent water from flowing down the unlined shaft from the lining above.”	The small amount of groundwater inflow into the shafts is effectively controlled through grouting. Seepage into the Exhaust Shaft is manageable and has reduced in volume during this reporting period. The source and content of such seepage are being characterized[c,d].
“The underground waste disposal facilities shall be designed to provide space and adequate access for the underground equipment and temporary storage space to support underground operations.” “The underground waste disposal facilities shall be designed to provide the capability of retrieving the emplaced CH and RH TRU waste.”	Geomechanical instrument data and visual observations indicate that the current design provides adequate access and storage space. W170 drift was trimmed/enlarged to function as a salt haulage route for the future excavation of Panel 2. Retrievability is not presently a requirement in the waste disposal program.

Table 10-1 (Continued)

Comparison of Excavation Performance to System Design Requirements

Requirement	Comments
"Entries and sub-entries to the underground disposal area and the experimental areas shall be provided and sized for personnel safety, adequate air flow, and space for equipment."	Deformation of excavation remains within the required limits. Normal periodic maintenance consisting of rock bolting, wire meshing, trimming, and scaling continue throughout the repository.
"Geomechanical instrumentation shall be provided to measure the cumulative deformation of the rock mass surrounding mined drifts. . . ."	Geotechnical instrumentation is operated and maintained to meet this requirement. This annual report acts to provide a summary and analysis of the geomechanical data. Geotechnical experts agree that the monitoring program at WIPP has been proven adequate, specifically with regard to the instrumentation in Room 1, Panel 1[e].

[a] Munson, D.E., D.L. Hoag, J.R. Ball, G.T. Baird, and R.L. Jones, 1995, "AIS Performance Tests, (Shaft V): In situ Data Report (May1988 - July 1995)," SAND94-1311, Sandia National Laboratories, Albuquerque, New Mexico.
[b] Holcomb, D.J., 1997, Memorandum to J.R. Tillerson dated September 29, 1997, "Summary of Air Intake Shaft Measurements (October 1, 1996 – September 30, 1997), WBS 1.1.03.6.1; Completion of Milestone RM103, Summary Memo of FY97 AIS Measurements," Sandia National Laboratories, Albuquerque, New Mexico.
[c] Intera, 1997, "Exhaust Shaft Hydraulic Assessment Data Report," DOE/WIPP 97-2219, prepared for Westinghouse Waste Isolation Division by Intera, Albuquerque, New Mexico.
[d] IT Corporation, 1997, "Composition and Origin of Nonindigenous Brine and Water in the Vicinity of the Exhaust Shaft, Waste Isolation Pilot Plant, New Mexico," DOE/WIPP 97-2226, prepared for Westinghouse Waste Isolation Division by International Technology Corporation, Albuquerque, New Mexico.
[e] U.S. Department of Energy, 1991b, "Report of the Geotechnical Panel on the Effective Life of Rooms in Panel 1," DOE/WIPP 91-023, Waste Isolation Pilot Plant, Carlsbad, New Mexico.
CH = contact handled
RH = remote handled
TRU = transuranic
WIPP = Waste Isolation Pilot Plant

The in situ performance of the excavations generally continues to satisfy the appropriate design criteria, although specific areas are being identified where deterioration resulting from aging must be addressed through routine maintenance and implementation of engineered systems. This deterioration has been identified through the analysis of data acquired from geomechanical instrumentation and the Geoscience Program. If the planned life of some of the openings needs to be extended, redesigning the geometry of the access drifts (e.g., changing the horizontal and vertical dimensions) or additional ground control (e.g., installing bolts, mesh, or slings) may be necessary. The ground conditions in the Waste Disposal Area and associated waste transport routes continues to slowly deteriorate; however, routine ground control installations and maintenance continues to allow safe access in the underground facility. Mining of Panel 2 and associated access drifts resulted in temporary increases in closure rates in Panel 1 and the southern portions of E300, E140, W30, and W170 drifts.

In addition to underground instrumentation, qualitative assessments of fracture development are documented through mapping the underground repository and inspecting the observation boreholes. The information acquired from these programs provides early detection of ground deterioration, contributes to the understanding of the dynamic geomechanical processes in the WIPP underground, and aids in the design of effective ground control and support systems.

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